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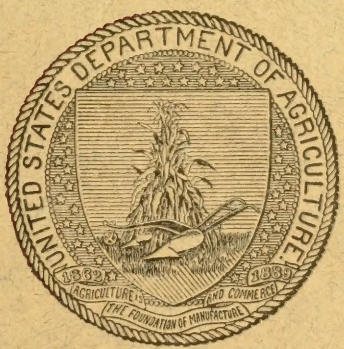
U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 159.
B. T. GALLOWAY, *Chief of Bureau.*

LOCAL ADJUSTMENT OF COTTON VARIETIES.

BY
O. F. COOK,
BIONOMIST, BUREAU OF PLANT INDUSTRY.

ISSUED SEPTEMBER 28, 1909.



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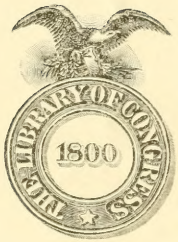

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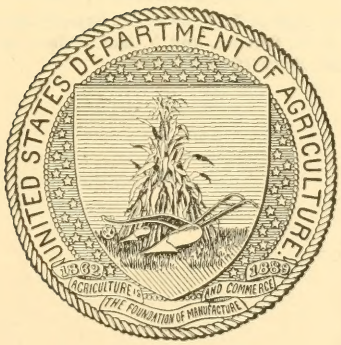

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BUREAU OF PLANT INDUSTRY.

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BIONOMIC INVESTIGATIONS OF TROPICAL AND SUBTROPICAL PLANTS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., June 25, 1909.

Sir: I have the honor to transmit herewith a paper entitled "Local Adjustment of Cotton Varieties," by Mr. O. F. Cook, and recommend its publication as Bulletin No. 159 of the special series of the Bureau of Plant Industry.

By maintaining local adjustment, crops can be improved, even without improving varieties. That new conditions and unfavorable seasons may render varieties less uniform has been known in horticultural plants. The present study shows that such facts have a practical application in field crops and that they must be taken into account in problems of heredity and breeding.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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LOCAL ADJUSTMENT OF COTTON VARIETIES.

INTRODUCTION.

A variety of cotton planted in a new place usually behaves in an abnormal manner. The abnormal behavior is generally proportional to the change of conditions, though different varieties respond in different ways to the same set of new conditions. Central American varieties of cotton grown for the first time in Texas usually show a definite alteration of the habits of growth and a notable decline in fertility. To lead an imported variety back to the regular expression of its normal characteristics and productiveness is called acclimatization. Varieties that do not remain entirely sterile under the new conditions can usually be brought back to their normal characteristics and fertility in from three to five generations.

When our Upland varieties of cotton are carried from one part of the cotton belt to another, or otherwise placed under new conditions, they also show deviations from their normal characteristics. Though the changes in the characters of the plants are very much less than with the imported varieties, they often have a serious effect upon the quantity and quality of the crop. To avoid this kind of deterioration, a process of local adjustment is required, analogous to acclimatization, but more readily accomplished.

Though local adjustment, viewed from the biological standpoint, is a much less striking phenomenon than acclimatization, it has a much greater and more general agricultural importance. The difficulties which have to be surmounted by acclimatization are met only in the introduction of new varieties from remote regions. It is only when we consider the advantage that might come from the successful introduction of better types of plants or of plants better adapted to special conditions or uses that acclimatization becomes a subject of general interest.

Local adjustment is of practical importance in quite a different way. The failure to make use of local adjustment does not result in a rare or occasional expense, but causes a very general and regular loss to the cotton industry, a loss that would be represented by enormous annual totals if the facts could be definitely known. Even at

a low estimate of 10 per cent, which is certainly far below the average, the increased crop which could be secured by attention to the facts of local adjustment would have an annual value of $60,000,000. With very slight expense of time and effort in the selection of seed for local adjustment, and with no other change, either in varieties, lands, or methods of culture, it would be possible to add 10 per cent to our cotton crop or to reduce the acreage and expense of production by a similar amount without reduction of the yield.

Our experiments in Texas lead us to believe that the losses occasioned by the boll weevil can be well-nigh made good if the advantage of local adjustment be added to those that can be gained by using better varieties and better methods of culture. This indication may not apply in the more humid districts in the eastern part of the State, but appears to have ample warrant in the western and southern parts, where our experiments have been made. Rainy weather during the growing season favors the rapid multiplication of the weevils and may enable them to ruin the crop in wet seasons, even in regions that usually escape serious injury, but these more severe attacks are usually confined to rather limited areas and are not likely to occur every year, whereas a continuous advantage can be gained from local adjustment. To maintain uniformity by local adjustment is especially important in weevil-infested regions as a means of securing the earliest and most uniform development of the plants, and thus allow the largest possible crop to be set before the weevils become destructively abundant.

The reader may be unwilling to believe that so simple an expedient as local adjustment should have been so long neglected if it has any such importance as claimed. The fact that notably increased yields of cotton, as of other crops, can be secured by selection of seed has not remained unknown, but the reasons why such improvements occur are not fully understood. The benefits that can be obtained at once from local adjustment have been confused with the much slower and more gradual changes that accompany the selection of carefully tested, exceptionally superior individuals. The emphasis that is often laid on special skill, precaution, and persistence as necessary qualifications for the successful breeder has tended to keep the average farmer from undertaking to improve his own crops by selection.

Local adjustment can be viewed as something quite apart from breeding for improvement; its object is merely to keep a variety as it is, instead of allowing it to deteriorate by becoming diversified as a result of changes of external conditions or of unfavorable seasons. No matter how superior a part of the plants may be it is certain that the highest yields can not be secured unless all of the plants are kept as near as possible to the standards of the variety. The better

the variety is the more serious the loss that comes from neglect of local adjustment, for the greater is the probability that every change from the characters of the variety will be in the direction of inferiority.

To know that yields can be increased by selection is a useful fact, but it is still better to have an adequate reason for it. A fact illuminated by reasons, so that the mind can follow and understand its relations, is what we call a scientific fact; a fact without a reason is called an empirical fact. It is often possible to utilize a fact without understanding it, but facts that we can understand are still more likely to be utilized. The art of farming includes large numbers of empirical facts that have come down to us as customs and traditions, but we take up very slowly and unwillingly any new method or operation unless a positive necessity or a very definite advantage can be shown. As long as the issue is not clear or the results are not so definite and invariable as to leave no room for doubt, the new requirement is likely to be avoided.

As soon as the farmer appreciates the fact that lessened uniformity is one of the chief causes of deterioration in cotton varieties he will also be convinced that the selection of his own seed is just as essential and necessary a part of his farm operations as the planting, cultivation, and harvesting of his crop.

It may be that local adjustment has not the same importance in other crops as in cotton, but here, at least, it is evident that the selection of seed for local adjustment is quite as important as any other work with the crop. A small amount of labor has a large effect on the final returns. Except for the picking of the larger crop it takes no more work to raise a well-adjusted strain of cotton than one that is deficient in adjustment. The selection of seed for purposes of local adjustment requires a certain degree of care and skill, but nothing beyond the ability to be found in the average farmer's family. The wife or the children may prove more capable than the farmer himself, and their assistance need not be refused, since the work is easy and enjoyable.

In thus pointing out the practical advantages that are to be expected from local adjustment, there is no intention to imply that the results will always be the same as those that have appeared in our experiments. The factors that are involved in local adjustment are highly variable, in the very nature of the case, since they have direct relation to variable external conditions. The details of the experiments given in this report are introduced as illustrations of the different ways that the factors of local adjustment have appeared to work, not as adequate demonstrations of local adjustment, even for the varieties and the conditions under which our experiments have been made. If the facts of diversity and local adjustment were rare

or exceptional there might be need to establish them by more elaborate evidence, but they are readily accessible to observation, if not already familiar to students of cotton. A more general recognition of their practical importance may be expected to secure for them the careful attention of experimenters.

DIVERSITY AS A NEW-PLACE EFFECT.

When a high-grade variety of cotton or of any other cultivated plant is grown in a new place and fails to give as good results as in its home locality, it is usual to draw the conclusion that the conditions of climate or soil of the new locality are unfavorable to the variety. Even when no unfavorable factors are known, it is still usual to trust to the assumption that some peculiarity of the variety renders it less suited to the new surroundings than to the old. It does not surprise us that a carefully selected variety fails to appear to the same advantage outside of the region in which it was developed. The selection of plants for purposes of agricultural improvement must always have reference to the external conditions under which the selection is made. Nevertheless, it is as distinctly a mistake to ascribe too much to the special adaptations of varieties as to leave this factor out of account. We must learn what we can regarding the nature of the changes that take place under new conditions, and of the possibility of avoiding them.

When a variety of Upland cotton planted in a new district fails to attain the standards of the variety, it is usually very easy to show that inferiority of the new conditions is not the only cause of the failure, or even the chief cause. Comparison of the individual plants with each other will soon make it evident that they are much more unlike among themselves than any reasonable supposition of inequality in the conditions would explain. Many individual plants are likely to be found which have not fallen below the previous standards of the variety.

The best of the plants, rather than the worst or the general average, represent the proper test of the possibilities of the variety under the new conditions. The unequal behavior of the plants will often be found to be a larger factor in the low general average than any definite limitation set by the external conditions. If the best plants are as good as in the home locality of the variety we may have an assurance that the new conditions are not in themselves directly and essentially unfavorable, for in that case none of the plants would be able to attain the fully developed characters of the type. The crop may be damaged as much by changes that arise in the plants as a result of new conditions as by factors that actually limit the growth of the plants, but the nature of the damage is different in the two cases.

The more carefully the matter is studied the more evident it becomes that the failures of many individual plants to show the true characteristics of their variety when grown in a new place are connected with differences in the plants themselves and are not directly connected or proportioned to the differences in the conditions occupied by the various individuals. The greater diversity shown among the members of the variety in the new place explains the apparent deterioration. To avoid this diversity and thus maintain a more general conformity to the normal characters of the type is the object of local adjustment.

External conditions that are actually unfavorable to the growth of the plants may be less conducive to undesirable new-place effects than conditions that are distinctly better for an acclimatized or locally adjusted stock of the same kind of plants. This was conspicuously shown in an experiment with imported types of Upland cotton at Falfurrias, Tex., in 1907. In the rows that ran out into drier and more sterile soil a large proportion of the smaller plants in the dry soil kept nearly the normal characteristics, whereas among the larger plants in the better soil only a few individuals remained small and normal. The few small plants in the moist soil and the few large plants in the dry soil showed that individual differences in the plants were able to fully counteract the differences in the conditions.

The inspection of even a few fields with such distinctions in mind is likely to convince any person who is at all familiar with such cotton that diversity among the plants themselves is a factor of practical importance in the diminution of crops and deterioration of varieties. Something in the way of special training or of natural aptitude may be required to give one a full appreciation of this diversity as a concrete, scientific fact, and to enable comparisons to be made between amounts of diversity that are present in different stocks of cotton or in different localities. Some persons appear to be as distinctly lacking in the necessary powers of perception of minor differences of form as others are of shades of color, but it is believed that most people will be able to recognize the forms of diversity that figure in the local adjustment of cotton varieties.

NEW-PLACE DIVERSITY DISTINCT FROM FLUCTUATING VARIATION.

The chief difficulty that has interfered with the recognition of the phenomena of diversity by scientific students and experimenters is not that they are not readily visible, but that they have been confused with other types of variation, such as the ordinary fluctuating differences, accommodative changes, direct effects of environment, and diversity due to hybridization.

Diversification under new conditions represents a fourth group of facts quite different from the other three and much more related to the phenomenon of mutation, as described by De Vries. The progeny of divergent plants may be expected to show fluctuating differences like the members of other varieties, and mutative changes may affect the same characters that are subject to accommodation, but such facts need not prevent the recognition of essential differences. That seedling plants are able to become more diverse among themselves when grown in a new place, even in the first season, and that these diversities have a relation to external conditions are facts not commonly recognized.

The recognition of these new-place diversities does not depend upon the systems of measurements that have been applied to fluctuating variations. Careful measurements of large numbers of plants or animals may lead to the recognition of differences that would not otherwise be detected, but in this case the differences are readily appreciable by direct observation. If the cotton plants that show diversity had to be detected by elaborate systems of measurements, local adjustment would be altogether impracticable. A considerable body of scientific workers would be needed for a whole season to give an adequate statistical account of the diversities of a single field of cotton. It may be obvious at a glance that the leaves of a plant are narrower than those of its neighbors, but many hours might be required to measure, record, and compute with proper care the data that are necessary for a mathematical determination of the actual differences of proportion that are responsible for the general impression. The leaves of the same cotton plant are so variable among themselves that a large number would need to be measured before general averages could be established.

And even after a statistical difference has been ascertained it might still convey a very inadequate idea of the diversities that figure in local adjustment. Mutative changes seldom appear to affect one character alone, and do not obey the law of regression established by Galton. Unlike the fluctuating variations which may be thought of as mere deviations from the same course or standard of heredity, mutative changes render the plants essentially different throughout, often quite as different as the members of distinct species, or even more so. Indeed, one of the serious objections to the idea of mutations as new species lies in the fact that the members of mutative varieties of domesticated plants are much more alike among themselves than are the members of wild species living under natural conditions.

To describe the mutative variations of our cotton varieties as new species would be a very formidable undertaking and may be left to

those who believe that mutations are really species. The present report is intended only to call attention to the fact that such variations are of frequent occurrence in cotton, that their numbers are still further increased by changes of external conditions, even to the extent of injuring crops and causing varieties to deteriorate, and, finally, that these dangers are to be avoided by continued selection for local adjustment.

NEW-PLACE DIVERSITY DISTINCT FROM ACCOMMODATION TO EXTERNAL CONDITIONS.

Changes of characters that have definite relations to external conditions are usually called adaptations or accommodations. Writers on evolution and heredity have recorded many examples of plants and animals that show accommodations to different conditions. Among the most familiar instances are the amphibious members of the buttercup family that have ordinary rounded leaves when growing on land, and very narrow, finely divided leaves when growing in water. The same individual can be induced to change the form of its leaves by planting it in water or taking it back to dry land.

The larger, thinner leaves that the coffee plant produces in the shade will not endure exposure to the sun, so that shade-grown seedlings usually lose all their leaves when planted in open places. If the change is not too severe the plant is able to adapt itself to the new conditions by putting out smaller, narrower leaves of firmer texture able to endure exposure to the sun.

Similar changes occur in the stature and habits of growth of the cotton plant in response to differences of environment. In one locality every individual will be larger and have more numerous vegetative branches than any individual of the same variety as it grows in some other locality. In localities where the winds are strong some varieties develop stiffer stems that resist the wind, while others avoid the need of such resistance by assuming a prostrate habit of growth and sending their branches out along the ground. Two selections from the same stock of Mexican cotton showed the same habits of growth at Victoria, Tex., but at Del Rio one of these developed a stronger central stem than at Victoria, while the other became notably prostrate.

Our experiments with the acclimatization and local adjustment of cotton varieties have made it certain that there is another class of changes of characters, those that accompany changes of external conditions, and yet stand in no such direct relations with the external conditions as do the adaptive or accommodative changes. Though accommodative changes may often appear to make members of the same species unlike they are not thought of as rendering them more

diverse or individually different. An accommodative change may be shared by all the plants with as much uniformity as any other feature.

Many of the changes of characters that occur in new places, instead of rendering the plants better fitted for the new conditions, render them less fitted. This is certainly true of the instances in which the plants that change their characters are rendered unproductive or completely sterile. A wild plant that behaved as many of our newly imported varieties of cotton have done would have no prospect of surviving. And yet several of the varieties that were nearly sterile in the earlier generations have returned to normal habits of growth and fertility after a few years of acclimatization.

Experience with these more profound changes that attend the process of acclimatization has made it easier to appreciate the nature of the diversity that necessitates the careful adjustment of varieties to local conditions, even in our United States Upland type of cotton, where the stage of acclimatization was long since passed.

Since many of the changes of characters that occur under new conditions obviously do not serve purposes of adaptation, and often result in wide individual differences, even under the same external conditions, it is evident that they ought not to be considered as due to accommodative changes of characters, but rather as resulting from loss or disturbance of adjustments of heredity previously established by selection or by mutation. We may inquire, therefore, into the nature of the adjustment of characters that is disturbed when a variety is planted in a new place, to gain an indication of the possibility of restoring the adjustment and regaining a uniform expression of characters under the new conditions.

The fact that the diversity that appears under a new environment is not the same as a regularly established accommodation does not compel us to deny that new-place diversity may have an adaptive value, since it allows a species to make tests, as it were, of the many forms that its members are able to assume. The forms that prove to be best adapted to the conditions are most likely to survive, and the species may thus secure a better footing than if compelled to keep to a form less suited to the new surroundings. Thus we may consider new-place variations as experiments in accommodation or as affording the materials from which the more definitely accommodative characters may be developed.

It is often assumed that natural selection must have the same tendency as artificial selection to reduce the members of a stock to a condition of uniformity in their environmental relations. Natural selection, however, is a composite of many factors often completely opposite. A dry season that gives the plants a selection for drought resistance may be followed by a wet year that tests their progeny for

ability to endure excessive moisture. The advantage would not lie with the lines of descent that specialized exclusively on drought resistance or on flood resistance, but with those that kept the two contrasted qualities represented in the family, either by producing progeny of two kinds or by combining the two qualities in the same individuals. Even though all the drought-resistant individuals were wiped out in a particularly wet season the drought-resistant characteristic need not be lost to the species, but might continue undiminished in transmission.

Much emphasis has been placed upon natural selection as an agency for producing greater uniformity through the weeding out of the lines of descent that yield weak or defective individuals, but this is not a reason for holding that the survivors are made more uniform among themselves by natural selection. The tendency is rather to preserve and combine all the different characters that give increased abilities or powers of resistance.[a]

RELATION OF NEW-PLACE DIVERSITIES TO HEREDITY.

The agricultural superiority of a carefully selected variety depends largely upon the greater uniformity that follows persistent selection. Wild or unimproved types differ from our high-grade varieties not so much in a complete lack of the desirable characters as in a failure to produce the desirable characters with sufficient regularity. Success in the art of breeding is largely a matter of securing uniform progeny from desirable parents.

With seed-propagated field crops like cotton, uniformity of characters is established by persistent selection. The breeder reduces and eliminates the individual diversity that renders a wild or unimproved stock inferior for agricultural purposes to stocks that have been improved by selection. By rejecting all the individuals that express other than the desired set of characters, much higher averages of the desirable features are secured by the breeder. A still more effective method is to preserve only those individuals that bring the desired characters to the highest degree of expression.

It is often supposed that a sufficiently thorough course of selection is able to completely eliminate the undesirable diversity of characters from a domesticated variety, but it is very doubtful whether the ancestral diversity is ever destroyed, in the sense of ceasing to be

[a] For a better appreciation of these tendencies of natural selection to maintain diversity in species and preserve the extremes of expression of environmental characters, the writer is indebted to Mr. A. F. Woods. The point has an evolutionary bearing, since it suggests a way in which natural selection may assist evolution by preserving diverse tendencies among the members of the same species and thus allowing the most advantageous combinations to be built up.

transmitted. With the most favorable conditions and in varieties that have been bred with the utmost care, individual examples of diversity continue to appear more or less frequently. No complete uniformity is ever attained. Even in vegetative varieties of plants grown only from cuttings or in varieties of wheat that are regularly self-fertilized, variant individuals are still to be found. That the original diversity of characters has continued to be transmitted, even in these most uniform types, is also shown when hybrids are made, and a large number of the ancestral diversities reappear at the same time and under the same external conditions.

These considerations make it quite unnecessary to suppose that the diversities that crop out among the members of a variety in a new place are impressed upon the plants by the external conditions. We are fully warranted in believing that much of the diversity represents inherent transmitted characters which have been able to come back into expression because the change of conditions has disturbed the previous adjustments that selection had established. It is not necessary to suppose that the diversities shown in the new place are different in any essential respect from the relatively rare individual sports or mutations that appear in the varieties, even under accustomed conditions. The chief difference is that the new conditions call forth many of these variations at the same time. Instead of sporadic mutations of single individuals, we often obtain in a new place a simultaneous promiscuous mutation of many individuals, sometimes of all the individuals, each becoming definitely unlike any of its neighbors, even when large numbers are carefully compared.

Viewed in this way it is possible to understand what our experiments show to be a fact, that even a relatively large disturbance of heredity shown by a variety of cotton planted in a new locality does not afford a sure indication that the conditions are unfavorable. And where the conditions are not unfavorable it ought not to be considered impossible to restore the previous uniformity of the stock by renewing the process of selection that established the uniformity in the first place. Experiments have also shown that such readjustments are readily established, at least in the cotton varieties with which experiments have been made.

A COMPARISON OF DIVERSITY IN TWO LOCALITIES.

To gain definite information regarding the nature and extent of the diversity which is aroused by planting a variety of cotton under slightly different conditions, a careful comparison was made between two fields of Triumph cotton—one at Lockhart, Tex., the other at Kerrville, Tex., in the season of 1907. Both of these localities are in the west-central part of Texas. Lockhart lies 63 miles northeast of

San Antonio, at an altitude of about 500 feet, while Kerrville is 71 miles to the northwest, with an altitude of about 1,700 feet. The soil conditions as far as they affect the size of the plants do not appear to be seriously different.

The Triumph cotton is known to breeders as one of the most regularly uniform varieties. It was originated at Lockhart by Mr. Alexander Mebane, and has been carefully selected by him for a considerable series of years. It would be difficult to imagine better examples of uniformity in a variety of seed-propagated plants than are afforded by Mr. Mebane's fields of Triumph cotton. A careful inspection of about 50 acres of Mr. Mebane's cotton resulted in finding only three plants that appeared to be definitely different from their fellows.

Immediately after this test of diversity had been applied at Lockhart, and with the uniformity of the Triumph cotton at that place as a basis of comparison, a similar study was made of a much smaller field of cotton raised at Kerrville, Tex., from seed grown by Mr. Mebane at Lockhart. The difference in diversity between the two places was very striking. Adjacent individual plants were often obviously unlike, and a considerable percentage of the plants could be reckoned as showing distinct departures from the Triumph type.

If the facts were to be interpreted in the usual manner, any observer would have felt fully justified in saying that the conditions at Kerrville were much less favorable than at Lockhart, for many of the plants were distinctly inferior in size and fertility and many of the smaller individuals remained quite sterile. It would be very natural, of course, to use these small and unproductive plants as examples of unfavorable conditions, but other facts showed that this explanation was insufficient. In addition to many small plants that remained completely sterile, there were numerous others that had unusually small bolls, different from those of the Triumph cotton. Other peculiarities of habits of growth rendered these small-bolled plants closely similar to inferior plants that appear among our Central American cottons during acclimatization. Moreover, these peculiar plants with the small bolls were notably later than those that kept the normal Triumph characteristics, so that no ripe seed could be obtained.

In addition to the small-bolled plants there were many other individuals that showed less violent departures from the normal Triumph characters, but still very definite differences. The nature of these differences is indicated in the following notes that were made on a series of selections of variant plants, in order to test the inheritance of their divergent characters:

(1) Plant tall; bolls rather varied in size and shape, broad but long pointed, sometimes with groove in the middle of the carpel at

the tip; lint abundant, long. The next plant in the row, apparently normal, had lint only half as long.

(2) Plant very open; basal internodes of the branches very long; lint long; seed smooth.

(3) A very small, low, short-jointed plant, with two branches at each node, possibly a result of injury to the main stem.

(4) Rather larger than its neighbors. Branches all rather long, only one from a node; bolls rather large, all but one with five locks; seeds very large, smooth, with a light-brown ridge along one side.

(5) Plant vigorous; bolls large, not notably different from Triumph; seed rather small, greenish; lint very fine, silky, especially in one boll.

(6) Small plant, about 1 foot high, with light foliage; small bolls, rather narrow and pointed; fruiting branches very short, with only two or three internodes, three of the branches with only one leaf and a boll; lint fine, medium; seed small; bracts connate at base.

(7) Plant large and vigorous, notably more fertile than neighbors; branches long; lint very abundant and of good length; seed green, rather small.

(8) Plant medium, open, either not vigorous or very early and determinate. Most of the leaves already moribund (determinate). Leaves rather long pointed, but some entire without lobes; bolls small, narrow, pointed, some with only three locks, others with four and five; seed smooth.

(9) A small, low, spreading, double-branched plant. Seed with short green fuzz in upper part and long white fuzz below.

(10) A very large plant with long, simple, and double branches and long basal internodes; large Triumph-like bolls; seed very smooth with a small brown tuft at base; lint of medium length, fine.

(11) A large, open plant with long branches, ripening more bolls to date than any of its neighbors, perhaps also determinate; lint not long, but abundant; numerous aborted seeds with lint developed.

(12) A small, open plant with four rather long slender vegetative branches; fertile branches of one or two internodes; only one boll, very small.

(13) A vigorous, long-branched plant; very hairy, notably more so than any of its neighbors, on the stalks, branches, petioles, peduncles, and bracts, and on the veins of the lower surface of the leaves.

(14) Plant vigorous, but not oversized; leaves rather gray-green with long, rather narrow lobes; very short primary branches pushing out at all the nodes and giving the main stem a leafy appearance;

stems unusually hairy, but somewhat less than in the preceding; bolls small; lint short; more fertile than the neighboring plants.

It became evident that the diversity alone would account for a considerable diminution of the crop at Kerrville without resorting to the idea that the conditions were really less favorable than at Lockhart. Many individual plants that retained their normal characters were also as fertile as at Lockhart. A further test of the possibilities of normal behavior for the Triumph cotton under the Kerrville conditions was afforded by the adjacent experiments with cotton of the same variety which was being grown for the second time at Kerrville. In this there was no such amount of diversity and no such obvious disparity of yield among the individual plants as in the plot grown from the seed newly brought in from Lockhart.

The fact that our Upland varieties of cotton are not uniform, but usually show a large amount of diversity among the individual plants, has been generally remarked by breeders and experimenters. Stress has usually been laid upon the idea that breeders of varieties have not been sufficiently careful and persistent in selection or that there has been a relapse to diversity through admixture of seed in ginning or through cross-fertilization with other varieties in the field. The following conclusions were reached by Dr. J. F. Duggar, director of the Alabama Agricultural Experiment Station, where a long series of tests of cotton varieties has been made:

> Man has done quite as much as nature to increase the confusion as to the varieties of American Upland cotton. The chief difficulty that has been encountered in the attempt to describe and classify cottons grown at Auburn under several hundred different names has been the absence of uniformity among the plants of a single variety. While this variability is partly due to natural agencies, it is also largely due to the failure of growers to avoid the mechanical admixture of the seed of other varieties, which so easily occurs at public gins. Worse still, in the case of many, perhaps most, of the so-called varieties, there has been no long period of selection through successive years with a view to fixing a uniform type.[a]

But whatever the causes of diversity in other varieties, it is evident in the case of the Triumph cotton that a variety which has been brought to a notable degree of uniformity in its home locality may at once become diverse when transferred to another district, at no great distance, and even under conditions that are not really unfavorable to the variety, as shown by the readiness with which it returns to uniformity after selection for local adjustment.

[a] Descriptions and Classification of Varieties of American Upland Cotton. Bulletin 140, Alabama Agricultural Experiment Station, July, 1907, p. 24

TESTS OF INHERITANCE OF DIVERGENT CHARACTERS.

As a further means of determining the nature of the differences that appeared in the Triumph variety as a result of the transfer from Lockhart to Kerrville, seed was saved separately from fourteen plants that seemed to show the most definite divergence from the varietal characters of the Triumph cotton. The seeds of these individual selections were planted at Kerrville in 1908, but a late frost killed most of the seedlings, in some cases all. Nevertheless, enough of the plants remained to make it very evident that some of the divergent characters were definitely inherited.

Plants noted as having branches with unusually long basal internodes and very open habits of growth (Selection No. 2) gave progeny of the same kind, very definitely contrasted with the progeny of low, compact, short-jointed plants, which showed a similar fidelity to parental characteristics. Some of the tall plants were noted by Mr. Rowland M. Meade as having the leaves and branches arranged in a one-third spiral instead of the usual three-eighths spiral, which would account for their more open form.

A plant (No. 9), selected because of a pronounced tendency to produce two branches from each node of the main stem, gave progeny in which this character was similarly pronounced, much as in the weevil-resistant Kekchi cotton from Guatemala. If this peculiarity had not been noted in the first generation, the second generation might have been suspected of being a Kekchi hybrid.

Another case of the same kind was found in a plant selected for unusual hairiness of leaves and stems, giving a distinct suggestion of approach to the more hairy Central American types of cotton, which was definitely repeated in the second generation (Selection No. 13). Another mutation with the hairy characteristic definitely expressed and as definitely inherited also had leaves with somewhat narrower lobes than in Triumph cotton and more commonly 5-lobed, as often happens in the Kekchi cotton. It also showed in both generations a distinct tendency to develop a short primary branch at each node, giving the main stalk an unusually leafy appearance (Selection No. 14).

Many other examples might be given in which mutations of our Upland cottons showed interesting resemblances to the Central American Upland types, as though to indicate a common ancestry for the whole Upland series. One of the most frequent approximations of this kind occurs in small, broadly branching, tree-shaped plants with very small bolls, as already noted in the general account of the Triumph mutations at Kerrville. From the only small-bolled plant which afforded ripe seed only one plant was raised, and this had

notably small bolls, though it retained the Triumph character of short fruiting branches, as the parent plant had also done.[a]

Peculiarities of the lint and seeds were also definitely inherited in the progeny of the Triumph mutations, though not with complete regularity. Notably long-linted parents gave notably long-linted progeny, short-linted parents short-linted progeny. The smooth-seeded character was retained in several instances, though not in all, while the tendency to a green color in the fuzz of the seeds was less in the second generation than in the first.

None of these mutations of Triumph at Kerrville were as conspicuously different from the parent stock as a plant that was pointed out to us by Mr. Mebane in one of his Triumph fields at Lockhart in 1906. This individual was about twice as tall as its normal Triumph neighbors and large in proportion. Its vigorous upright habit of growth and its foliage, of a somewhat lighter, fresher green, rendered it quite conspicuous. The bolls were as large as those of the Triumph variety, but the plant seemed much less fertile than the parent stock. A few seeds that happened to be ripe were saved, not only to test the inheritance of the variation, but to learn whether its fertility would be increased in subsequent generations. Six plants were raised from these seeds at Victoria, Tex., in 1907, all closely similar to each other and to the parent plant. The progeny of 1908 still kept closely to the parent form, but a report from Mr. John H. Kinsler indicates that the fertility is distinctly increased in the third generation.

Better fortune attended another experiment of the same kind at San Antonio. A similar series of selections of divergent plants was

[a] A very striking instance of approximation to the Kekchi cotton in a mutation of an Upland variety was observed by Mr. F. J. Tyler at Auburn, Ala., in 1907, and described by him in a letter to Mr. F. L. Lewton, under date of October 15, as follows:

"It is a Guatemalan cotton mixed in with Sunflower long staple. Of course it is a mutation or reversion, but it could hardly be more like Kekchi or Pachon as they look when grown in Texas for the first time. It is a large, rounded bush filled with sterile limbs, very late, nearly as pubescent as Kekchi and has the little bracts at the sinuses of the involucre. It is just beginning to bloom, and there is no hope of obtaining seed, as frost may be expected in a couple of weeks. It doesn't resemble Sunflower in any way, but must be a Sunflower plant. In 1905 Professor Duggar selected some seed from the best plants of Sunflower, and the seed cotton was carefully ginned and put away until this spring, so the seed was two years old. They have never had any Guatemalan cotton seed here at the station. On each side of this plant in the same row are typical Sunflower plants with bolls mostly open. I have taken a couple of photographs of the plant."

The photographs fully confirm Mr. Tyler's statement of the very close similarity of this mutation to the newly introduced Kekchi cotton. The shape of the plant and its method of branching, as well as the shapes, positions, and texture of the leaves, appear indistinguishable from those of the Kekchi cotton.

made in the season of 1907 in a plot of King cotton. Seven plants which seemed to show the most definite individual peculiarities were selected, their peculiarities noted, and their seed saved separately to see whether the same peculiarities reappeared in the progeny. The nature of the differences manifested in the selected individuals and the extent to which they appeared in the progeny can best be shown by following the original notes made at San Antonio in 1907 and 1908.

Behavior of original stock.—As a basis of comparison of the behavior of the mutations another planting was made in 1908 from seed held over from the same stock in which the various mutations had appeared. This row grew next to the mutations and consisted of very uniform, rather low open plants about 2 to 2½ feet high. Only one plant seemed to differ in any definite way from the others. It had numerous sterile involucres consisting of only one or two bracts. There were also many simple leaves and a few with unusually narrow lobes.

Variant with strong basal limbs.—The plant selected in 1907 was unusually large for that season. It was about 30 inches tall, and was also more vigorous and leafy than the average. There were 3 long, strong, sterile basal limbs and 22 bolls, maturing late. The plants were notably larger and stronger than original King, and bore a distinctly larger crop of bolls.

The progeny of this plant in 1908 were very uniform among themselves and differed notably from the row of original King in their larger size, larger leaves, more compact habits of growth, and stronger development of basal limbs. They produced a larger crop of bolls and a more uniform quality of lint. They were also larger than the parent plant of 1907, but this was generally true in all kinds of cotton grown at San Antonio.

More detailed comparison with the original King row established the fact that there were several other differences that had not been noted in the individual selection of the previous year. The leaves had somewhat longer and more pointed lobes. The lint was notably superior to that of the original King row, being longer, more abundant, and more uniform. The lint was also superior to that of the other mutations, though most of these appeared better than the original King, perhaps because of a greater degree of uniformity.

Variant without basal limbs.—Selection of 1907 a plant of medium size (2 feet tall), with the main stalk naked at the base for 8 inches and no sterile basal branches. Leaves relatively few, with shallow lobes.

The progeny of 1908 showed a marked contrast with the preceding row, especially in the habits of growth. Instead of the more compact form and larger leaves, these plants were much more open and had

fewer, smaller leaves. There was a general lack of sterile basal limbs, leaving the stalks naked for several inches above the ground. This peculiarity was even more obvious than the unusual development of such limbs in the preceding row. The greater luxuriance of the plants brought, as might have been expected, a greater tendency to produce basal limbs than in the parent plant of the year before. Such branches were present on several of the plants, but to no such extent as in any of the other rows. There could be no doubt that the form of branching was definitely inherited, following a definite variation in this character in the preceding year.

One plant appeared somewhat different from the others, in having more abundant, longer lint and a tall, erect habit, with short fruiting branches, most of them with only one boll. It also had two strong basal limbs, and developed many new vegetative shoots late in the season.

Variant with numerous primary limbs.—The plant selected in 1907 was next to the largest (30 inches tall). There were sterile basal branches, but a primary limb developed at nearly every node, along with a fertile branch, as in the Kekchi cotton of Guatemala.[a] Of the nodes 11 produced 2 branches each. Of the 17 bolls more than half were deformed and decayed before opening; only 1 perfect boll remained.

The progeny did not follow the parent in the lack of sterile basals, but there was a much stronger tendency than usual toward the development of primary limbs. This would naturally be accompanied by a smaller development of limbs in plants that were less vigorous, like those of last year. Sterile basal branches, or "limbs," come from internodes which do not produce fertile branches, because the limbs represent transformed fertile branches.

Compared with the preceding series this row of plants appeared quite low, rather spreading, very leafy, and compact. They were not quite as uniform as the more upright and taller plants of the preceding mutation. The bolls did not appear defective, showing that this feature was probably only accidental in the preceding year.

Variant with compact habit of growth.—Selection of 1907 a small, productive, early, large-bolled plant; 15 inches high; 18 bolls; no basal limbs.

The progeny of 1908 appeared not greatly unlike those of the next preceding series, but they averaged distinctly smaller and kept more

[a] In the Upland type of cotton the vegetative basal limbs (also called wood limbs) can usually be looked upon as modified fruiting branches since they arise from extra-axillary buds, as do all the fruiting branches. The axillary buds may not develop or may do so only late in the season, but axillary buds are always found to produce only vegetative limbs that do not produce fruit directly, but may give rise to a new series of fruiting branches.

uniformly to the low, compact, leafy form. Later in the season these differences appeared still more notable. Most of the plants appeared to have strong limbs, but in many cases these were found to arise from primary buds that had started late in the season, instead of being transformed fruiting branches, which usually form the "limbs" of our United States Upland cottons. Early in September this row showed a great abundance of strong new shoots, more than any of the preceding rows, which still appeared relatively dormant. This might be connected with the greater earliness noted in the parent plant. The bolls continued distinctly larger than in original King, but mostly because of larger seeds; the lint was only a little better.

Variant with entire leaves.—Selection of 1907, a sturdy plant, 14 inches high. No sterile "limbs," but 3 small primary branches, each from a node that also had a fertile secondary. Fertile branches beginning close to the ground. Bolls 21, larger than usual in King.

The progeny raised in 1908 appeared closely similar to those of the previous selection in the next row in size, habit, and general appearance. They differed, however, in the much greater frequency of entire leaves, though this feature had not been noted in the parent. The habits of branching were much as in the last row. Some of the plants had basal limbs formed from sterile secondaries, but many of the apparent limbs were true primaries. The lint averaged distinctly better than in the last selection and also better than in original King, but not as good as in the first mutation.

Variant with smooth seeds.—Selection of 1907, a large plant, 30 inches high, with 3 good-sized basal limbs and 21 average King bolls. Seeds smooth and black, except for a brown tuft at the beak.

Progeny of 1908, 30 plants—5 with smooth seeds, 8 with seeds nearly smooth, 10 intermediate, and 7 with fuzzy seeds. The habits of branching appeared to be quite as varied as the characters of the seeds. Axillary limbs were sometimes developed, though many plants had none, but had instead two or three large extra-axillary limbs. Several of the plants had no limbs except as some of the axillary buds had grown out into fresh shoots late in the season. This is distinctly different from the behavior of the other rows where mature limbs were found at many of the joints, along with the fruiting branches.

Variant with narrow leaves.—The plant selected in 1907 was nearly 3 feet high, twice as tall as any other plant in its row. It had 2 long, sterile basal branches and narrow-lobed leaves, varying from small, entire, and lanceolate to those that were distinctly okra-like, deeply cleft into 3 to 5 narrow lobes. There were 7 empty involucres, composed of 1 or 2 bracts, and 20 very small late bolls.

The progeny of 1908 consisted of 34 plants, with a general similarity to the parent in size, habits of growth, and other characters, but also with distinct differences among themselves. Sterile extra-axillary limbs and axillary limbs seemed to be indiscriminately developed; the primary limbs were often as large as the others. Some plants had no limbs developed, others no large primaries; many had both kinds of vegetative branches graded in size, the lower axillary limbs nearly as large as the extra-axillary limbs.

The forms of the leaves showed equally definite variation. Of the 34 plants 1 had leaves of an extreme okra type, 13 had leaves of intermediate form but still distinctly okra-like, and all were more deeply cut than in Egyptian cotton. Finally there were 20 plants with normal broad leaves. In spite of much diversity in the size and shape of the leaves of the individual plants this separation of the plants into groups appeared to be very definite. Three persons picked out independently the same 20 plants as belonging to the broad-leaved group, though some of them showed, on careful inspection, a prolongation of the lobes beyond anything found in the original King row.

The empty involucres of the parent plant were definitely represented by irregular formations of the bracts, especially on the narrow-leaved plants. Among the 20 broad-leaved plants several had involucres with only 2 bracts more or less distorted and unequal, though only 4 had completely sterile bracts. Among the okra-leaved plants aborted buds were much more common, though 4 of the 13 intermediate plants did not show them.

In addition to this series, many other mutative variations of King and Upland varieties have been tested, with the same general results. Some have proved remarkably constant from the first, while others show less constancy or readier response to admixture with the parent stocks. One of the cluster variations of King, which are of very frequent occurrence, was tested at San Antonio in 1907, the progeny of a very prolific single plant raised at Victoria in the preceding year. The progeny showed the cluster habit in a very definite manner and were as uniform and as fertile as any other row of King, with the possible exception of a San Antonio selection. A few of the plants seemed to have definite differences, one having the very small, late-maturing bolls that mark a not infrequent form of degenerative reversion in many Upland types. It was also noted that the plants at the ends of the row, those that had a better supply of water, showed the cluster habit more distinctly than other plants more stunted by drought.

DIVERSITY WITHOUT HYBRIDIZATION.

The relation of these diversities of the King cotton to change of conditions is not so definitely established as in the case of the Triumph, for there was no previous opportunity to observe the degree of uniformity attained by the King under its original conditions. The King is also much more inclined than the Triumph to show definite forms of diversity, often accompanied by the cluster habit or shortening of the branches. On the other hand, this more variable tendency of the King gives greater significance to the fact that the variations are definitely inherited and do not behave after the manner of hybrids, though it is usual to ascribe the diversity of King to careless breeding or to admixture of seed. The fact ought also to be taken into account that the King cotton originated in North Carolina and is the most northern variety now being planted in Texas. The fact that a native Texan variety as uniform as the Triumph is also subject to similar diversities ought to be taken into account in attempting to understand the behavior of King.

Numerous plantings from the same stock of King seed in Texas in different localities and different seasons have shown different degrees of diversity. The most extreme instance of diversity was in Guatemala, where a planting of King yielded only two or three individuals with the usual characters of the variety. The others were as distinctly diverse among themselves as they were different from the normal type. The diversity was conspicuously greater than in any other United States variety included in the experiment; in fact, it exceeded the diversities of all the other Upland varieties taken together. While none of our Texas plantings of King has given an equal display of diversity, they have given us numerous examples of the same kinds of differences in individual plants. Similar facts are reported by Dr. D. N. Shoemaker, who has had much experience with this variety in Texas.

The possibility that the peculiarities of the selected plants of King cotton were due to hybridization seems to be excluded by the notable uniformity with which the peculiarities were repeated in the offspring. Such uniformity in hybrids is quite unknown. If the plants selected in 1907 had been first-generation hybrids their offspring of 1908, representing the second generation, should have displayed a full range of the differences of their grandparents. Instead of this, the progeny of different selections are often strikingly uniform among themselves, though differing notably as groups.

Such facts do not permit us to doubt that the changes of characters aroused in a variety of cotton when grown in new localities are of the same nature as the relatively rare mutative variations or sports that may appear without transfers to new localities. With

greater changes of external conditions there are larger possibilities of arousing diversity. The definite inheritance of these changed characters in the next generation shows that the deterioration of a variety through the diversity called forth by a transfer to new conditions is not spontaneously corrected, but must be eliminated by new selection.

A large proportion of the diverse characteristics are not those of other recognized varieties, but are such as to render the plants unsuited to agricultural purposes—characteristics that would never be preserved by selection in an agricultural variety. Thus the small-bolled, late-maturing plants which appeared in considerable numbers in the Triumph field at Kerrville, Tex., were quite unlike any of our Upland varieties of cotton, though they are very similar to the dwarf, depauperate forms that occur very frequently during the period of acclimatization of the Kekchi and other Central American relatives of our Upland cottons.

While such facts do not show that hybridization may not have taken place farther back in the history of a variety, they show that the possession of the diverse characteristics is not to be explained by the theory of hybridization alone; the existence and continued transmission of characters not regularly expressed in our agricultural varieties has to be recognized. To account for all diversities by hybridization is to assume that there was an original, ancestral condition of uniformity when all the members of the stock had one and the same set of characters, and that this ancestral set of characters would have remained uniform if no hybridization had occurred. As soon as we recognize that diversity, rather than uniformity, represents the original condition there is less necessity to resort to remote possibilities of hybridization when diversities appear.

The tendency of many different types of cotton to show repeated mutations of the same kind or in parallel directions is an interesting phenomenon that has already been recognized in other plants by Mr. W. W. Tracy, sr., of the Bureau of Plant Industry. Mr. Tracy's extensive acquaintance with many varieties of garden vegetables has convinced him that there are general tendencies to variation running through whole natural orders of plants quite independent of the characters that have been used as the basis of selection in developing useful varieties.

The different plants of the same natural order tend to vary along parallel lines. Fruit of the variety of tomatoes known as Early Conqueror, those of the pepper known as Squash or Tomato-Shaped, and of the Scarlet-Fruited eggplant could be selected, which would be as much alike in form as fruits from a single plant of any one of them; and I have seen a "potato ball" of the same form. I have found fruits of squash, muskmelon, watermelon, and cucumber each having the peculiar forms and markings generally confined to one of the others. Thus, last year, I found a plant of watermelon whose

fruit was distinctly warted, and in form would pass for a fairly typical one of Summer Crookneck squash. I have seen muskmelons as flat and deeply scalloped as a fair sample of White Bush Scalloped squash—squashes as well netted and distinctly ribbed as a Bay View muskmelon. And it is taste and usefulness rather than limitation of variant tendency which determines the common shapes of these vegetables. I believe that hybridization is often credited with variation which is due to this common variant tendency.

Thus, the Lima bean, originally a climbing plant, continued so for many years, during which time several distinct races were developed, but no dwarf form appeared; then, within three years, dwarf forms of all the different racial types appeared, and in several different places simultaneously. The sweet pea, cultivated for many years and closely watched by many enthusiasts, gave only climbing plants until 1892, when the "Cupids," or dwarf forms, appeared in at least three locations and different stocks and five individuals, and since then they have appeared in a great many different stocks and places, and often where there could not have been pollen influence to induce the sport. In most vegetables, if any new form, no matter how distinct from those commonly cultivated, appears in one stock and place, there is almost a certainty that practically identical variations will appear elsewhere. For instance, the Navy Blue sweet pea was a very new and distinct shade and appeared in the fields of two cultivators the same year, the only discernible difference in the two sports being that the seed of one had a greater tendency to skin-crack than that of the other. This tendency to sport into new forms developing in the species rather than in any particular stock is often the cause of much annoyance to seedsmen, two or more of them being accused of sending out a new form under different names, when each supposed that he had the only origination of that type.[a]

While the theory of hybridization does not enable us to explain these parallel tendencies of mutations, they are not in conflict with the idea of a persistent transmission of ancestral diversities. The occurrence of similar variations like the small-bolled cotton plants through a whole series of diverse varieties is itself a reason for believing that this characteristic is present in the ancestry of many different kinds of cotton. Vigilant selection is able to prevent the continued expression of this character in any of our improved varieties, but it does not appear that there is any way of preventing this characteristic from reappearing in occasional mutative variations. The small-bolled character in cotton may be compared to the red ears of corn that continue to appear even in our most carefully selected varieties, or to the black sheep that appear occasionally in the most careful pedigreed stocks that are known to have been bred for large numbers of generations without the preservation of a single black individual.

It is not necessary to suppose that all of the forms of diversity that appear without hybridization are in the nature of reversions or reappearances of characters of remote ancestors. Many of the peculiarities of mutations may be viewed as examples of the suppression

[a] Tracy, W. W., sr. Variant Tendency and Individual Prepotency in Garden Vegetables. Memoirs of the New York Horticultural Society, vol. 1, p. 76. 1902.

of characters. Characters that continue to be transmitted may suddenly fail to come into expression. If the normal color of a plant or animal depends on the formation of a green or black pigment in the cells the failure to produce this pigment results in the formation of an albino. Large numbers of white varieties exist among animals, for in these organisms the pigment is not indispensable, but plants can not grow without their green pigments, or chlorophyll, unless they are parasites or saprophytes. Albino seedlings occur, as in the Voorhees Red variety of sweet corn, but never grow to maturity.[a] When albinism is limited to stripes or spots the plants may survive, as in ornamental varieties with variegated foliage.

The process of leaf development requires a very fine adjustment of the processes of growth among the different kinds of cells that form the upper and lower surfaces. If these adjustments are disturbed the plants are unable to develop leaves with even surfaces, but produce leaves that are irregularly crumpled or swollen out between the veins (bullate). Such irregularities in the formation of leaves are a frequent characteristic of mutations in many different families of plants, as in cotton, coffee, tomatoes, and capsicum. They are also characteristic of many varieties of lettuce and cabbage.

It is likewise apparent that the symmetrical building up of regularly columnar internodes or joints of the stems of plants requires nice adjustments of the process of growth. If heredity becomes disturbed so that normally straight internodes are not formed, the stems of the plants are unable to maintain their usual upright position, but can only trail along the ground or droop. This trailing or drooping tendency, like the bullate leaves, is a frequent characteristic of mutations of plants that usually have upright habits of growth. Numerous instances of prostrate cotton plants have been observed, and the same tendency is shown among the variant forms in many other families of plants.

Internodes may also become abnormal by failure to develop to a normal length, as in our "cluster" and "limbless" varieties of cotton. Such varieties of cotton apparently correspond directly to the bush varieties of beans, squashes, and dwarf peas mentioned by Mr. Tracy, and afford another instance of a familiar form of mutative change that extends through many different families of plants. The shortening of the internodes in cotton is usually confined to the extra-axillary branches that bear the fruit, and does not affect the axillary vegetative branches which share the functions of the central stalk.

[a] Halsted, B. D. Experiments in Crossing Sweet Corn. Bulletin 170, New Jersey Agricultural Experiment Station, p. 19. 1904.

INCREASED YIELDS FROM LOCAL ADJUSTMENT.

To ascertain the amount of injury to the crop that might come from these changes of characters under new conditions, as distinguished from really unfavorable factors of climate or soil, adjacent plantings were made of seed raised and selected in the new place in the previous year and of other seed from the same original stocks of seed held over from the same lots, from which the previous year's planting had been made. Very definite differences were found in such plantings, showing that the selection of seed from plants that do not show changes of characters in the first year secures more uniform progeny in the second year. It is easier to understand this if we recognize the fact that the planting of a variety in a new place is in the nature of a test of the stability of the characters of the different individuals under the new conditions. The fact that the changes of characters are definitely repeated is itself a reason for expecting that the plants that do not change their characters in the first year will also have less tendency to changes of characters in the second year, and this seems to be the fact, at least with the Triumph cotton and some other varieties that have been tested in the same series of experiments.

The differences between the first-year and second-year plantings at Kerrville in the season of 1907 were in every case in favor of the second-year planting over the first, though the advantage gained in some of the varieties was much greater than with others. The Hawkins variety showed 5 per cent, King 9, Cook's Improved 11, Triumph 18, Parker 26, and McCall 33. In the case of the Triumph the actual yield from the Kerrville-grown seed was 37 per cent in excess of the yield from seed of the same original lot planted for the first time, but the stand of the latter was not complete, so that the percentage had to be estimated. The average rate of increase favoring the Kerrville-grown seed was 16.4 per cent. It was also plain before the cotton was picked that the second-year rows were superior in the size and fertility of the plants, especially in the cases of the Triumph and Parker varieties. The rows contained about 50 plants each and yielded seed cotton in amounts of from 3 to 6 pounds. These rows were alternated in such a manner that no inequalities of conditions could be supposed to have unduly influenced the results. The second-year rows were better whether they were above or below the first-year rows on the gentle slope where this series of plantings was made.

The careful comparison of rows of plants grown close together gives the best opportunities of ascertaining their inherent differences. With cotton grown under field conditions it is impossible to protect

large numbers of plants against inequalities of soil. In this experiment at Kerrville, for example, it was very evident that the comparison of larger plots would have given much more unequal results. The Triumph cotton in the row tests was distinctly superior to the Triumph cotton grown in the closely adjacent field planting on the land which would have been used if a system of large plots had been employed to test the yields on a more extensive scale. Even on the level prairies of Texas the texture and composition of the soil is often extremely irregular, and the plants often reveal the existence of serious differences not visible before. The experiments suggest that the most satisfactory way of making yield tests of cotton in Texas is to plant two kinds in repeated alternation so that the inequalities between rows of the same kind can be compared with those of rows of different kinds. The same standard, locally adjusted variety may be used as a basis of comparison for different tests, but only by growing it in each case with the variety to be tested. Such yield tests ought to be made quite apart from breeding experiments, for the amount of cross-fertilization is likely to be very large.

It was noticed by Mr. F. L. Lewton in 1906 that the Hawkins and McCall varieties succeeded much better at Kerrville than in any of the other points in Texas where experiments were made. This fact may indicate that the Kerrville conditions were more similar than those of other localities to the home of these varieties in Georgia and South Carolina. Normal behavior of a variety in a new place means that the gain from local adjustment would be small, as proved to be the case with the Hawkins variety with respect to the yield, though the lint was distinctly better in the second generation at Kerrville.

A fairly satisfactory measure of the yield can be obtained by counting the numbers of bolls on the plants, without waiting for the actual picking of the cotton. First-year plants at Del Rio, Tex., showed on September 8, 1908, an average of 63 bolls per plant, while second-year plants at the same place had an average of 88 bolls. The counting of the bolls before they are ripe may not be a safe index of the crop, for the plants are often unable to ripen all the bolls that are set, but there is no obvious objection to the use of the number of bolls as a measure of the tendency to fertility from the standpoint of local adjustment.

OTHER TESTS OF LOCAL ADJUSTMENT.

In addition to the decrease of diversity and the increase of yield, several other standards for judging the progress of a variety toward local adjustment have been suggested by facts observed in these experiments.

While the yield is the most important test of local adjustment, it has not proved very convenient in connection with our experiments, because of the necessity in most places of making two or more pickings if all of the cotton is to be secured. Some varieties are likely to lose much more cotton than others if the crop is allowed to stand too long before it is gathered, and even in the same variety the earlier ripening of a locally adjusted row might result in an apparent lessening of the crop if stormy weather "scattered" some of the lint from the earliest bolls.

IMPROVED QUALITY OF FIBER.

The effect of local adjustment on the quality of the fiber is sometimes quite as striking as the general superiority of the plants in uniformity and yield. In the Kerrville experiments, where the increased yields were obtained from the locally adjusted rows, there was also a very distinct gain in the quality of the fiber. The method followed in judging of this improvement was to compare each plant of a row grown from Kerrville seed with its nearest neighbor in a row grown from the same original stock of seed held over for such experiments.

In some of the varieties the differences between the rows that represented first and second plantings of exactly the same stock were very striking, almost all the plants of the second-year rows showing better lint than those of the first-year rows. This was true particularly in the King, McCall, and Hawkins varieties, but in the Parker rows there was so little difference in the quality of the lint that the superiority of the second-year row appeared doubtful. In the McCall and Hawkins rows it was noticed that the plants in which the cluster habit was most pronounced never had long and abundant lint. On the other hand, such plants were often distinctly inferior, with only short and sparse lint.

INCREASED EARLINESS.

Increased earliness is an important factor in its bearing upon the yield to be obtained in regions infested with the boll weevil. It is quite possible that the larger yields of locally adjusted varieties at Kerrville were due, at least in part, to greater earliness, which allowed them to mature and to set more bolls before the boll weevil became destructively numerous. It is possible, however, to test the question of earliness apart from the question of yield by observing the times when the plants begin to flower or the bolls begin to open. Countings were made at Del Rio, Tex., in 1907, of the numbers of open bolls on first and second year plantings as a means of determining whether

there had been a gain in earliness in maturity of bolls. Though the conditions at Del Rio were distinctly less favorable than at Kerrville for the display of local adjustment differences, the second-year rows showed larger proportions of open bolls at the date of our visit, September 30.

In the King variety a first-year row of 22 plants showed an average of 11.6 open bolls to the plant, while a row of 26 second-year plants gave an average of 12.8 open bolls. In the Hawkins variety 24 first-year plants had an average of 5.8 open bolls, while in the second-year row the average was 6.9. In the Parker variety the average for 25 first-year plants was 9.2 open bolls, while for 22 second-year plants the average was 11.4. In the first-year Triumph row only 8 plants had survived, but these gave a higher average, 9.37, of open bolls than 16 second-year plants, whose average was 6.06. In this case it appeared that unfavorable conditions had not only reduced the numbers of the plants and stunted their growth, but had also brought about a premature opening of the bolls on some of the plants that remained. Two of the first-year plants had 16 and 17 open bolls, respectively, whereas the two highest plants of the second-year series had only 15 and 16 bolls. Both these rows of Triumph were very much inferior to a third row, representing a selection made at Victoria in the preceding year, which showed at the same date an average of 15.75 open bolls per plant. In the season of 1908 countings of first-year Parker plants at Del Rio showed an average of 8.8 open bolls, while an adjoining second-year row gave an average of 13.5.

For the benefit of those who may wish to make special selections for earliness in view of the advantage of early cotton in avoiding injury from the boll weevil, it may be well to notice the fact that there are several different factors of earliness that have different values in relation to the boll weevil. Early opening of flowers or of ripe bolls is not the form of earliness that is most needed as a protection against the boll weevil. The essential factor is the early setting of the bolls and prompt development to mature size, beyond the danger of weevil injury. Experiments with Central American varieties of cotton have shown that there are great differences in the readiness with which the different types open their bolls. In some varieties the bolls are opened as soon as they are mature, while in others the mature bolls may be held without any apparent change for a considerable period without opening. Some of the East Indian varieties of cotton do not open their bolls, the cotton being shelled out by hand after the bolls have been gathered. After a boll has passed the period of susceptibility to weevil injury there is no particular advantage in having it open early. The cotton of very early bolls is likely to be lost or damaged unless the number of pickings is increased.

The influence of local adjustment upon earliness is increased by the fact that the number of bolls that can be produced early in the season is directly dependent on the method of branching followed by the plant. The main stalk of the cotton plant produces two distinct kinds of branches, the fertile branches that bear the bolls and the vegetative branches that produce other fertile branches, but no bolls. If the young plants begin the formation of vegetative branches instead of fertile branches there is a definite postponement of fruiting, for no flower buds can be set until the fertile branches are formed. The study of the new-place diversities shows that changes in the methods of branching are one of the most frequent forms of variation.

LARGER BOLLS.

Progressive increases in the sizes of the bolls have been found by Mr. F. L. Lewton in successive plantings of cotton representing different generations of the same original stock in the same locality. In the Parker cotton raised at Winfield, Kans., in 1908, a ten-boll sample of seed cotton produced by a first planting weighed 55 grams, the ten bolls representing the second season at Winfield weighed 65.8 grams, while ten of the third season weighed 72.9 grams. The Hawkins variety showed 58.8 grams for the ten-boll sample of the first season, 53.8 for the second, and 61 for the third. In the Triumph and McCall varieties it was possible to compare the bolls only for the second and third seasons, but in both cases there seemed to be a distinct increase, in the Triumph from 95.6 to 99.2, and in the McCall, 53.4 to 63.5. The proportions of 4-locked and 5-locked bolls were so nearly equal in these samples that this factor can not explain the results.

LARGER PROPORTIONS OF FIVE-LOCKED BOLLS.

Experiments in the acclimatization of types of cotton new to the United States have shown that the number of locks in the bolls is often greatly reduced in the first planting and gradually returns to normal proportions as acclimatization proceeds. The most striking example of this fact was brought to my attention at Falfurrias, Tex., by Mr. Rowland M. Meade. Countings of the bolls of 42 of the Kekchi plants showed a total of 42 three-locked bolls, 202 four-locked bolls, and 6 five-locked bolls. On the other hand, 7 plants of an acclimatized stock of Kekchi cotton grown close by yielded 5 three-locked, 81 four-locked, and 91 five-locked bolls. In the acclimatized stock about half of the bolls, 51 per cent, had five locks, a proportion similar to that of our United States Upland varieties, while in the planting of imported seed the 5-locked bolls had been reduced to less than 3 per cent.

Similar tendencies toward a reduction of the numbers of locks in varieties grown in new places have been shown in our United States Upland varieties, though to a very much slighter extent, as might be expected. Countings of locks of Parker cotton made by Mr. C. B. Doyle at Del Rio, Tex., in 1908, gave an average of 31 five-locked bolls per plant in a first-year row and 47 per plant on the second-year row, while the 4-locked bolls had advanced only from 32 to 41.

AGE OF SEED AND DIFFERENCE OF CROPS.

The method of testing the second and third generations of a variety of cotton in a new place has been to compare these generations with plantings of the same original stock of seed held over for this purpose. While it is difficult to see how a direct test could be made in any other way the plan might be open to objection if it could be shown that plants raised from old seeds were more diverse than those that come from seeds raised in the previous year. Though no formal test of the relation of age of seed to diversity has been made, it may be said that neither from our experiments with cotton nor from what is known regarding other plants is there any indication that old seeds are likely to yield more diverse progeny than are new seeds.

The evidence, such as it is, seems to be more favorable to the opposite idea that less diversity appears in plants raised from old seed. Our nearest approach to a definite test was at Kerrville, Tex., in 1907, where a row test with old Lockhart seed of Triumph cotton stood adjacent to a field planted with new seed from Lockhart. The plants raised from the old seed appeared distinctly better and more uniform than those from the new, though the experiments were not of such a character as to completely exclude the possibility of influence from differences of soils or dates of planting.

It has also happened in several of our experiments with the Central American types of cotton that seed 2 or 3 years old gave more fertile plants than had been secured from the first plantings of the same stocks in the same places. Though the possibility that more favorable seasons may be responsible for these differences is not to be excluded, the better results from the old seeds are at least worthy of note. If the undesirable diversity can be avoided or diminished by merely holding over old seed, an advantage might be gained in the acclimatization or local adjustment of varieties.

It seems rather remarkable that this question of differences between old and new seed has not been more carefully tested. The idea that old seeds are better, at least in the sense of being likely to yield more uniformly productive plants, is firmly established in the popular mind, especially among growers and dealers in the seeds of melons and cruciferous plants. The difficulty is to distinguish between the

possible influence of the factor of age and that of the factor of difference between crops of seed of the same variety.

It is stated by Mr. W. W. Tracy, sr., that seed dealers often come to recognize particular crops of seed as setting standards of excellence which later generations of the same stocks are not able to attain. A particular crop of seed of a variety of Savoy cabbage which came under the personal observation of Mr. Tracy gave progeny of greater and more uniform excellence than any other stock of seed that could be secured, not excepting the seeds grown from progeny of this same original lot, even when grown in the same field. The second generation, or grandchildren, was never equal to the first generation that came from the special stock of seed.[a]

Whether the retention of the later lots of seeds to an equal age would have given them the same excellence was not determined. Indeed, such a test would be very difficult in view of the fact that differences of age could never be equalized. Even though the popular idea of the superiority of old seed should be found to rest on the superiority of particular crops the continued excellence of these superior crops would still show that the increased age of the seed should not be supposed to make the progeny more diverse. It is to be expected that different crops of Triumph cotton raised at Lockhart might show differences of behavior at Kerrville, or even at Lockhart, but there is no reason to believe that this factor is of serious importance in comparison with local adjustment. The amount of diversity that appears at Kerrville is out of all proportion to the diversity that appears at Lockhart.

A similar idea, that uniformity increases with the age of the stock, is said to exist among breeders of new varieties of potatoes, who believe that bud variations are much more likely to occur in new varieties recently developed from seedlings than in old, long-established varieties.[b]

[a] "Seed of the same stock and equally well grown, by the same cultivator, in the same location, differ in the variant tendency and the degree to which their product will be of the desired type in different seasons. The crop of seed of Green Globe Savoy cabbage produced by a certain grower in 1893 gave much more evenly typical plants and heads than any subsequent crop produced by him of the same strain, though he took the greatest care in selecting stock and growing the plants, even setting them in the same field that gave the superior crop. I have known a practical seedsman, one not likely to waste money on a mere theory, to pay treble the market price for a certain strain of peas produced by him four years before, though he had an abundance of seed of the same strain grown by himself in succeeding years—none of these later crops giving such good results as seed of that particular season." See Tracy, W. W., sr., Variant Tendency and Individual Prepotency in Garden Vegetables, in Memoirs of the New York Horticultural Society, vol. 1, p. 77, 1902.

[b] East, E. M. A Study of the Factors Influencing the Improvement of the Potato. Bulletin 127, Illinois Agricultural Experiment Station. 1908.

Still further back, we find a similar idea in the theories and methods applied by the Belgian horticulturist Van Mons to the breeding of pears and other fruits a century ago. Van Mons made a practice of sowing the seeds of the first fruits of his seedlings, which were supposed to deviate more readily from the parental type than seedlings obtained from mature trees. Though horticulturists admit that Van Mons was able in this way to produce a large number of superior varieties, some of which are still popular, the value of the system has remained in doubt. Some have believed that it did produce a rapid amelioration as claimed, while others have ascribed the results to accidental hybridization as likely to be of frequent occurrence in his gardens, where large numbers of different types of fruits were crowded together with no protection against cross-fertilization by insects.

To explain the supposed worthlessness of the seedlings of old and superior sorts, Van Mons advanced the idea that the improvement had distinct limits and then suffered a sudden and complete decline. This idea appears to have been based largely on the inferiority of seedlings of some famous old southern varieties which had been carried into more northern regions. It is quite conceivable from the standpoint of the behavior of cotton that the change of conditions might render the seedlings of southern varieties inferior to those that Van Mons was able to derive from native Belgian stocks. A statement made by Downing in his discussion of Van Mons, that there was a marked and unexpected decline in the quality of seedlings raised by colonists in New England, also suggests the possibility that factors of acclimatization and local adjustment may have to be considered in the breeding of fruits as well as in annual crops.[a]

METHODS OF TESTING COTTON VARIETIES.

Failure to take into account the factor of local adjustment may vitiate any test of varieties. A new variety not really superior, but carefully selected and locally adjusted, may appear to be better than a really superior old variety, if the seed of the latter is brought in from a distance and the comparison is made without the precaution of local adjustment. Conversely, a really superior variety brought into a new place may suffer by comparison with inferior stocks which have the advantage of better local adjustment.

[a] "The first colonists here, who brought with them many seeds gathered from the best old varieties of fruits, were surprised to find their seedlings producing only very inferior fruits. These seedlings had returned by their inherent tendency almost to a wild state. By rearing from them, however, seedlings of many repeated generations, we have arrived at a great number of the finest apples, pears, peaches, and plums." See Downing, A. J., The Fruits and Fruit Trees of America, 1845, p. 7.

It is not safe to assume that any single planting can determine whether a new variety is suited to any particular set of local conditions. The only evidence that first plantings can give us is to show the extent to which new conditions can disturb the usual expression of characters of varieties.

The failure of tests of cotton varieties to yield practical results does not arise from any difficulty in finding differences between the behavior of different varieties of cotton when planted side by side. The trouble usually is that differences are too great and too frequent. A variety which in one year appears to be among the best may appear in the next year among the worst. The experimenter gains the impression that varieties of cotton have an extreme sensibility, not only to local differences, but to seasonal changes. This appearance of very great delicacy of adjustment makes testing appear almost in vain, especially in regions where the seasons are capricious, as in Texas. The experimenter gains no confidence in the uniformity of his results and is unable to give the farmer the practical advice that he desires.

The need of making allowances for local adjustment shows that any practical test must require at least two or three years before we can hope to ascertain whether a new variety is really well adapted to local conditions or not. Nor is it reasonable to suppose that the mere repetition of the usual tests for two or three years will furnish the desired information regarding the value of varieties. To make the test effective the experimenter must be acquainted with the normal form and methods of growth of the varieties so that he can select the plants that best conform to the varietal standards. It is only by the selection of the plants that fail to be disturbed by the new conditions that the possibilities of the variety can be ascertained.

The recurrence of diversity in a variety as a result of new conditions has some of the same effects as hybridization. The stock is no longer "pure," in the sense that it no longer yields uniform progeny. As the plants that have undergone definite changes of characters now differ in the same way as distinct varieties, a stock containing such mutations can no longer be said to represent a single variety; it has become a mixture of varieties and of crosses between them. Just as we would not think of beginning a variety test by mixing our seeds, so we ought not to consider that we can make a fair test of any variety after it has split up into other varieties.

The behavior of a variety in new places may very properly be tested from the standpoint of new-place variation to learn the nature, number, and extent of the changes that occur, and the practicability of avoiding them by acclimatization and local adjustment. Not until local adjustment has been accomplished, so that a variety behaves

with a normal degree of uniformity, does it become possible to make an adequate final test of the variety—a test which determines whether the variety is really adapted to the conditions and is really better or worse than other varieties also adjusted to the conditions.

It may be that some relation can be discovered so that we can judge from the first behavior of a variety what its later behavior will be. It appears reasonable, on the surface, to suppose that a variety which shows many changes in a new place will continue to be less stable than another variety that behaves much more normally in the first year. But a little further thought robs us of even this logical assurance, for it is easy to understand that the behavior of a variety in a new place may have more relation to the place from which the variety has come than to its inherent possibilties of becoming adjusted to the new place. A variety brought from similar conditions, so as not to be upset by the transfer, might appear at first distinctly superior to another variety which had not had any previous opportunity to gain adjustment to such conditions.

To judge from indications of the first season it would have appeared quite hopeless to expect any normal behavior from some of our imported varieties which showed complete changes of habits of growth and became almost completely sterile. And yet these same varieties have later returned to normal characteristics and fertility. In view of such facts it would seem that the minor aberrations of our domestic varieties can hardly be taken seriously as indications of special, exclusive adaptation to the conditions in which they happen to have been bred. These wider possibilities of adaptation give new importance to the testing of varieties, though at the same time they appear to greatly increase the difficulty of the work.

Not only must the tests be maintained for longer periods, but this very fact multiplies another element of difficulty, namely, that of protecting the varieties against admixture by cross-pollination while the tests are being made. This danger differs in different regions with the numbers of insects that visit the flowers, but in many localities it is quite unreasonable to suppose that a variety will remain pure after it has been grown for two or three years in close proximity to other kinds of cotton.

Thus it seems necessary to admit that very little practical importance can be attached to either of the two systems of testing cotton varieties that have been depended upon in the past. The farmer's planting of a small amount of seed of a new variety can not be relied upon to give him any true idea of the value of the variety, or even to place him in adequate possession of the variety. Neither does the assembling of a large number of varieties by the experimenter for tests of yields enable him to decide which is the best stock, even for the region in which the experiment is made.

A first application of the facts of local adjustment in the testing of cotton varieties has been made in connection with the Central American and Mexican types recently introduced because of their weevil-resisting adaptations. Astonishing claims of superiority for the new varieties could have been made if we had waited until acclimatization had been completed and then tested them in comparison with United States Upland varieties which had not been locally adjusted to the places where the imported varieties had been acclimatized. The differences are much less striking when the imported varieties are compared with the best of our Upland stocks which have received the same selective attention that the new types have had, and in the same places. Nevertheless, if the new sorts continue to hold their own or to excel under such circumstances their general use can be advised with much better justification.

If the imported varieties had been distributed for general planting without these more thorough tests and without taking the facts of local adjustment into account, the result would doubtless have been the same as in many other instances where new varieties of plants in the hands of the practical farmer or gardener fail to show the distinct superiority claimed by those who have originated or imported them. Such discrepancies are commonly explained as due to misrepresentation by the dealer or to the overenthusiasm of the breeder, but the phenomena of local adjustment show that differences of this kind may also have a basis of actual fact.

METHODS OF INTRODUCING NEW VARIETIES.

The bearing of local adjustment on the introduction of new varieties is quite as serious as upon methods of testing varieties. No matter how superior a variety may appear in one locality, where it may have been carefully bred and adequately tested, it is not safe to assume that it will show its superiority in other regions until it has passed through the process of local adjustment. Nor is it any longer possible to believe that the farmer can ascertain the true value of a new variety by the traditional method of making a small trial planting and saving the seed of this to use in later years for general crop purposes.

The facts of local adjustment show us that the first planting of even a carefully selected high-grade variety in a new place is likely to result in an immediate deterioration of from 10 to 20 per cent in the yield, and as much, or more, in the quality. Unless this deterioration is avoided by removing the changed individuals from the stock, subsequent generations may be expected to show a gradually increasing deviation from the standards of the variety.

Unless the farmer takes special precautions to isolate his new variety, which he is not likely to undertake for a small sample of seed, and may be unable to accomplish at all when his neighbors are growing other kinds of cotton, the new stock will be badly infected with hybrids by the time he has multiplied it and secured enough seed for regular field plantings. And if, on the other hand, the farmer does isolate his new cotton he will not be able to make a direct comparison with the variety he has previously grown.

And even if the farmer succeeds in avoiding mixture of pollen by insects, there is still to be encountered the almost equally serious difficulty of avoiding mixture of seed at the gin. It is difficult to imagine a system that would more effectively conspire against the maintenance of pure-bred varieties of cotton than our American cotton gin, where the seed from each farmer is likely to receive an admixture from any other farm or from many farms together. Unless the farmer takes the unusual pains to see that the gin machinery is thoroughly cleaned out before his special stock is ginned, he has no reason to expect that his new variety will escape admixture, no matter what his previous precautions may have been. And to have even the opportunity to have the gin cleaned, he will usually be compelled to store his cotton till the end of the season.

These difficulties will in general conspire to prevent any real test of a new type of cotton, for by the time this test can be made the variety will have become seriously deteriorated, both by variation and hybridization. In addition to this, it is to be recognized that even if an individual farmer were to take the necessary precautions of carefully selecting and isolating his new stock, the prospects of his being able to secure any direct advantage from his efforts would still be very unfavorable. Unless he is a very large producer, and is thus able to market his crop separately, he is not likely to secure any advance in price. Ordinary buyers would not give him a better price than they were giving his neighbor who had made no improvement in the quality of the product.

Thus it appears that an entirely different system of introducing new varieties of cotton is needed if their full value is to be secured for the farmer. The work must be planned from the standpoint of whole communities, instead of from that of individual farmers. The seed must first be locally adjusted to the new place and must be grown exclusively in the region if it is to be protected from mixing with other varieties. If the full value of improved strains is to be gained, whole communities must unite in their production, so as to supply special markets or to secure special attention in the trade.

The present multiplicity of cotton varieties is recognized as a very unfortunate condition from the commercial standpoint, as well as from the agricultural. A very large proportion of the varieties are

known only in restricted regions, to which they are supposed to be specially adapted. Reasons for this opinion have been found in the fact that these local favorites often fail to distinguish themselves when carried to other districts and yet are able to hold their own at home, even in comparison with high-grade varieties from other places.

While it is certainly to be expected that cotton varieties, like other kinds of plants, are really different in their adaptive characters, so that some are better suited than others to a particular set of conditions, the facts of local adjustment show us that it would be very easy to overestimate these special adaptations. Not until a new variety has reached the condition of local adjustment can the question of special adaptation to the local conditions be fairly tested, as has been seen in the preceding chapter. And until the importance of the factor of adaptation has been determined in this way we can not be sure that there is any practical necessity for the present multiplicity of varieties.

The number of varieties is increasing annually through the efforts of seedsmen to satisfy the popular demands for novelties. Superior new varieties should be welcomed, of course, but there is seldom any general agreement that the new varieties are better than the old. Though often widely disseminated by advertising, they are seldom able to supplant the old in any complete manner. No progress is made toward the desirable policy of uniformity for the whole community.

From present indications it appears quite possible that the factor of local adjustment may often prove to be larger than the factor of special adaptation. If this should be the case, much may be gained by extending a few of the best varieties over larger areas and discouraging the cultivation of all of the local varieties that can be replaced with others that are as good or better. Varieties that have an essential superiority will tend, of course, to maintain themselves and to spread into adjoining districts from the center where their superiority is definitely recognized. The problem is to facilitate such extension of good varieties by more definite determinations of their value in the outlying regions. A local variety called "Beat All," which has been grown and carefully bred in southern Georgia for nearly fifty years, is reported by Mr. F. J. Tyler as more popular in its home district than any other. Mr. Tyler considers this variety the best in the district, especially for poor lands, and states that it is fast replacing all other varieties. But when the same variety was tested (under the name "Hart's Improved") at the Georgia station, only 100 miles away, it stood at the bottom of the list. So great a contrast would not be likely to appear if tests were made between locally adjusted stocks.

Local adjustment may be looked upon as a plan for the establishment of many local strains of each of the more desirable varieties of cotton, but these strains are to be kept as much alike as possible in their commercial characters instead of each locality carrying on an independent selection based on an independent standard of its own.

Instead of taking it for granted that each locality must grow a different type of cotton, we ought to begin with the opposite idea of extending a few of the most desirable types as widely as possible through the cotton belt. Real limitations will doubtless be found after the varieties have been studied from the standpoint of local adjustment, but we should not assume that the limits have been reached until they are really encountered and we can learn what they are. Many experimenters with varieties of cotton and other crops have been content with the simple idea that the varieties are different, and have not felt any further obligation to ascertain the nature of the differences. Nevertheless, the need of more adequate knowledge in this field has also been clearly appreciated by some of our students of agricultural science. A very definite statement of this kind was made over twenty years ago by the late Dr. E. L. Sturtevant:

> The true study of a variety, to be of value, must embrace the properties of the plant, whereby certain adaptations are attained which render the variety better fitted for certain conditions of culture. Thus we would know of grain whether stiffness of straw or weakness of straw, whether ability to endure high cultivation or thin seeding or hardiness, etc., are an inherent property of the variety. We would know whether some varieties are more resistant to drought than others or can withstand wetness. We would know the relations of the plant toward conditions apt to occur in cultivation, and the better we know these, the more reliable become the conclusions which are derived and disseminated as an aid to the cultivator. * * * For us to say at the present stage of agricultural study that one variety is best, and inferentially that such a variety should be adopted by all, would savor of quackery. The best reports we can offer are the results of trial under conditions as noted and memoranda of variety peculiarities or such of them that we are able to definitely record.[a]

In this experimental study of cotton varieties from the standpoint of this distinction between local adjustment and adaptation to special conditions, so as to determine the true values of the different varieties in different parts of the cotton belt, the farmer is in particular need of the assistance of the Department of Agriculture and the State experiment stations. It is not to be expected that the efforts of individual farmers will be able to make adequate tests of this kind, for the number of varieties is too great and too much time and labor are required.

[a] Sturtevant, E. L. New York Agricultural Experiment Station, Fifth Annual Report for 1886, p. 71.

RELATION OF LOCAL ADJUSTMENT TO OTHER VARIATIONS.

ENVIRONMENTAL CHARACTERS ALSO HEREDITARY.

It is usual to think of the characteristics of plants and animals as contributed by two general factors, heredity and environment, some characteristics being assigned to one factor and some to the other. Much effort has even been spent in attempting to determine whether characters supposed to come from the environment could become hereditary. Some writers have considered that the environment was partly or wholly responsible for the evolutionary development of plants and animals, while others have denied even the possibility that characters acquired from the environment could become hereditary.

In the light of our present knowledge the distinction between hereditary and environmental characters appears less serious. The only difference seems to be that the so-called environmental characters are more readily changed and adjusted to external conditions, not that they are less hereditary than other characters. The readiness with which many characters can be accommodated to changes of environment have led many writers on evolution to suppose that such characters are not hereditary. It might with equal propriety be alleged that they are more truly and effectively hereditary than other characters, since their powers of accurate accommodation to a particular condition do not appear to be impaired by long periods of disuse or by varied experiences of other kinds which notably disturb the adjustments of characters that have less direct relations to the environment.

It is not necessary to suppose that any of the characters of plants or animals are directly due to the environment, or that any characters are entirely independent of environment. Changes of characters following changes of environment can be thought of as representing responses or accommodations to external conditions, or influences of the conditions upon the processes of heredity. These relations are sensitive in many different degrees with different organisms and with different characters. Some characters are greatly affected by changes of external conditions and others very little.

Changes of accommodation, like the round leaves which give place to narrow-lobed leaves when amphibious buttercups are grown in water or the changes from fruiting branches to vegetative branches in cotton, can be considered as regular reactions or responses to changes of external conditions. To recognize a change of characters as a response is not the same, however, as to suppose that the character itself is in the nature of a response to a condition. The narrow leaves are not thought of as being caused by additional water in the plant, but as being put forth by the plant as a consequence of the

change of conditions. The internal machinery of the plant that enables it to put forth the two kinds of leaves is something quite different from the air or the water in which the leaves may grow. The change of expression of the characters is an internal process, of which we know nothing except the visible result, that the plant takes on a different method of growth. While we do not understand the internal mechanisms that enable one environmental character to be substituted for another, there is no reason to consider this fact any more mysterious or any more significant from the standpoint of heredity than the further fact that characters may also change and alternate in expression without any regularly corresponding changes in the environment. In some kinds of plants, such as the juniper and the eucalyptus, the same individual may bear at the same time two very different kinds of leaves, showing that such differences lie, first of all, in the plants themselves, rather than in their environments.

CORRELATION OF CHARACTERS AND NEW-PLACE EFFECTS.

The phenomenon of correlation may also assist us in understanding the fact that new conditions call forth diversity. Correlation itself is only inadequately understood, but many examples have been collected by students of heredity. By correlation we mean that two or more characters tend to be brought into expression together. Correlation is said to be complete if one of the characters never appears without the other. Or there may be lesser degrees of correlation where the characters are more often found together than apart. As an example of a kind of correlation that is very general in cotton there may be mentioned the tendency of longer lint to accompany a narrower, sharp-pointed boll. This correlation not only applies to different species and varieties of cotton, but appears to hold even between individuals of the same variety. It is always to be expected that a plant with more pointed bolls than its neighbor will have longer lint. There is no obvious reason why this should be true, for the lint does not lie extended in the bolls, but is packed around the individual seeds. There is no apparent reason why a rounded boll should not contain long-linted seed as well as a pointed boll.

New-place effects observed in imported types of cotton appear to be regularly accompanied by correlated characters. Thus if the plants grow abnormally large and robust, the fertility is not only greatly reduced, but the number of locks in the bolls may be distinctly lessened as well as the amount, length, and quality of the lint. Such facts show that the changes called forth by the new conditions are not confined to characters that are usually supposed to be directly related to the environment. When great individual diversity appears, however, we are carried beyond the idea of correlation as

usually understood, and have to fall back upon the idea already suggested that the changing of the accommodation characters may carry with it a disturbance of the internal relations which control the expression of the other characters.

The phenomena of correlation are worthy of careful consideration in our attempts to understand the workings of the internal machinery of heredity. The general correlation or tendency for smaller and more rounded bolls to produce short lint may render the lint liable to deterioration through any external agency that affects the shape of the bolls. At Yuma, Ariz., in 1908, a considerable series of Upland types of cotton included in our experimental plantings showed a very general tendency to small rounded bolls, and there was an equally general shortening of the lint.

It also appears to be a rule with the Upland cotton that luxuriant growth tends not only to reduce fertility and make the crop late, but also to render the lint inferior. Thus at Del Rio, Tex., in 1908, several selections of the Parker and other types of Upland cotton, which grew more luxuriantly than in 1907, showed distinctly inferior lint. In some cases the progeny of plants that yielded notably good lint in 1907 gave not a single plant with good lint. The advantage which appeared to have been gained in the year before from local adjustment was much less apparent in 1908, as far as the lint was concerned. It was noticed in several cases that the plants with the best lint were at the ends of the rows where there was more exposure to light and less competition of roots. Thus it appears that luxuriant growth does not necessarily conflict with the production of good lint, but that overgrowth, along with overcrowding and overshading, is regularly accompanied by deterioration of the staple. That unfavorable conditions might reduce the number of bolls on the plant would not be surprising, but there is no obvious external reason why the lint inside the bolls should be so definitely affected by the external conditions, unless it be through correlation with the form of growth adopted by the plants. If we can determine the extent to which the lint of different bolls of the same plant may be affected directly by differences of temperature and sunlight a better idea of the importance of this correlation may be gained.

ENVIRONMENTAL CHANGES ACCOMPANIED BY INCREASED DIVERSITY.

When we study with greater care the changes that occur under the new conditions, we find that they are not confined to characters that are directly connected with the external conditions, those that are shared by all the plants in the new environment. We find that these more general changes of accommodation to external conditions are

often accompanied by even more definite changes in the individual plants that greatly increase the amount of differences among them. To transfer a variety from a moist to a dry region may result in the plants being more hairy, but it is also likely to result in some plants becoming more varied in other characters of their leaves than they were in the previous locality. The increase of diversity is just as concrete a fact as the change of accommodation, and often more important for agriculture, since it is this diversity that lessens the crop rather than the general change of characters in the direction of accommodation to the new conditions.

The undesirable increase of diversity may be considered as an indirect result of the change of conditions incidental to the more regular accommodative changes of characters which changes of environment call forth. It does not seem unreasonable to suppose that the making of one readjustment among the characters should disturb another adjustment in mechanisms as delicate and highly complex as organisms. But whatever the explanation, the facts remain that diversity is increased by new conditions and that this diversity causes deterioration and decrease of the crop, and that these injuries can be avoided in later years by renewed selection to establish and maintain the local adjustment of the variety.

Changes of accommodation that are shared by all the individuals can be related to different factors of the environment, heat, light, moisture, or substances in the soil. To investigate these relations is more the object of the science of ecology. The diversity shown by the different individuals constitutes another group of phenomena, less directly related to ecology than to the science of heredity itself. The same internal instability is likely to be aroused by a very different external change. It has been observed that the mutations that arise in one place are no more alike among themselves than those that arise in a very different place. In seeking to understand such diversities we study first the behavior of the plants themselves, rather than their environmental relations. We no longer hope to explain the origin of particular characters by particular conditions, but accept the organisms and their varied characters as already existing. We must seek to know the facts of behavior before attempting to change them.

EFFECT OF SEASONS AND TIMES OF PLANTING.

An unfavorable season may have the same effects upon variation as a transfer into a new region, as already noted. The seasonal differences in the same place may even exceed those of different places quite widely separated. An excellent example of this has been noted by Mr. F. L. Lewton. A white-seeded Mexican cotton grown at Victoria, Tex., in 1906, and at Falfurrias, Tex., in 1907, retained the

white-seeded character without variation, but in the season of 1908 the same stock planted again at Falfurrias showed a considerable number of distinctly greenish seeds, and still larger numbers of seeds slightly tinged with green or brown, and only a small proportion of seeds of the original white color. This change occurred not only in plants grown from seed raised at Falfurrias in 1907, but also in those raised from some of the seed of 1906, the same stock of seed that had produced only white-seeded plants in 1907. Thus there seems to be no room for doubt that the conditions at Falfurrias in 1908 were able to effect a change which had not been called forth by transfer from the Mexican State of Durango to Texas.[a]

A similarly general change in the habits of branching of the Parker variety of Upland cotton occurred at Del Rio, Tex., in 1907. No less than six plantings of different stocks of seed of this variety showed a distinct tendency to depart from the normal long-branched habit of this variety and go over to the semicluster habit, as a result of a shortening of the joints of the fruiting branches, as already described in a previous report.[b]

Though there could be no doubt that the conditions were responsible for strengthening this tendency to shorter branches there is also no reason to suppose that the shorter joints represent a character that came in from the environment. It is a matter of observation that the tendency to vary in the direction of shorter joints is very general, not

[a] Two cases of differences in the seed characters of the same individual plants in different parts of the season have been noted by Mr. Lewton. In a picking of a selected plant of Mexican cotton at Del Rio, Tex., October 3, 1907, all the seeds were coated with olive-green fuzz. Another picking made October 22 showed about half of the seeds nearly smooth. In the bolls picked from a selected plant of the Pachon cotton from western Guatemala at Yuma, Ariz., November 11, 1907, there were 42 per cent of smooth seeds, while in an earlier picking from the same plant (September 9) almost all of the seeds were fuzzy, though in neither case were the seeds as heavily coated with fuzz as is usual with the Pachon cottons.

That changes in the color of the fuzz are likely to occur as a result of transfer from Guatemala to Texas was also shown by a plant of Kekchi cotton at Kerrville, Tex., which produced 42 per cent of grayish green seed. This plant was from a stock of seed specially selected by Mr. Lewton in Guatemala, where the Kekchi cotton has the seeds densely covered with white fuzz with great regularity. Large amounts of seed from numerous localities in the Cahabon district of eastern Guatemala have been examined by Mr. Lewton without finding any smooth seeds or colored fuzz. Many examples of colored fuzz have occurred in the second generation of the Kekchi cotton in the United States, but the possibility of hybridization was not excluded. Hybrids usually have green fuzz. See Reappearance of a Primitive Character in Cotton Hybrids, Circular 18, Bureau of Plant Industry, U. S. Department of Agriculture.

[b] Cook, O. F. Suppressed and Intensified Characters in Cotton Hybrids. Bulletin 147, Bureau of Plant Industry, U. S. Department of Agriculture. 1909.

only among varieties of cotton but in many other plants. The tendency is more frequently manifested as a definite change or mutation of an individual plant growing, it may be, with hundreds or thousands of others that do not change. The behavior of the Parker cotton at Del Rio is of interest as showing that external conditions may at times interfere to accelerate or intensify a tendency to change that under other conditions would remain entirely latent.

Even the time of planting may have a definite effect upon the habits of growth and fertility of the plants, as can be easily seen when the same kind of cotton is planted in adjoining rows at different dates. Very early plantings, if they are not actually killed by frost, may be seriously injured by cold weather so that the plants make very slow growth. Many individuals may remain permanently stunted, or if they finally grow to full stature may do so only late in the season and produce no early bolls.

Plantings made somewhat later, that begin their growth while the weather is still cool, but without being stunted, have a distinct tendency to produce fruiting branches low down on the stalk, and are thus able to set an early crop of bolls. Late plantings, that begin their growth in warm weather, become too luxuriant at first and produce sterile vegetative branches at the base of the plant, instead of fruiting branches. The result is that the cotton that is planted too late in the season may require a longer time to set the same number of bolls than an earlier planting of the same cotton in the same place.

These facts explain the failure of experiments that have been made with very late plantings, in June, in order to "starve out" the boll weevils in the spring months. Even if no boll weevils were present these very late plantings could not be expected to yield as well as the earlier plantings. In the presence of boll weevils there may be a total failure of the crop.

The facts also explain why in southern Texas plantings made in April and May often yield larger crops than plantings made in March. Conspicuous examples of this were observed at Del Rio, Tex., in 1907, where fields planted in April and May were distinctly better than March-planted fields, in spite of the fact that weevils were present in abundance early in the spring in cotton that had survived the winter. In an experimental field planted May 22 the crop was uninjured even as late as October 2. Most of the plants remained entirely untouched by the weevils, showing no punctures on squares or bolls.

The ability of later cotton to overtake and outyield earlier plantings, even in the presence of the boll weevil, was definitely shown in a succession of plantings of Triumph cotton at San Antonio, Tex.,

in 1907. A planting made on March 8 was not only outyielded by adjacent plantings of March 23 and April 7, but the later plantings actually ripened larger proportions of their crop before the 1st of September. The yields for the three dates of planting stood in the proportion of 1,109 pounds per acre, 1,220 pounds, and 1,190 pounds, whereas the corresponding percentages of cotton ripened before September 1 were 65, 69, and 76. The more rapid development of the April and May plantings produced buds and bolls faster than the weevils were able to destroy them. The growth of March plantings may be so seriously retarded by the effects of cold weather that the production of weevils overtakes the cotton, especially if one or more of the early crops of buds are blasted and "shed," as often happens when the plants are checked by unfavorable weather.[a]

AGGREGATE AND PROMISCUOUS MUTATIONS.

The behavior of the Parker cotton at Del Rio shows that it is sometimes possible for external conditions to induce a change in the expression of a character that can also change without any apparent relation to external conditions, as when a single individual mutation occurs among many hundreds or thousands of plants that remain without change. The simultaneous mutation of all the individuals of a planting shows that the conditions of that planting have favored mutation. Though they do not prove that sporadic individual mutations that occur in other places are caused by external conditions, they do show that the two kinds of changes are not so essentially distinct as often supposed. Clocks that are able to strike by their own mechanism may also be induced to strike by external interference with the mechanism, though the striking itself may be the same in both cases. It is not necessary to suppose that there is any fundamental difference between mutations that take place spontaneously as the result of changes in the organic mechanism itself and those that appear to have more direct relations to external conditions. Whether many mutations occur, or a few, or a single one, the nature of the mutations may be much the same. Nor need we think that the relations to the external conditions are fundamentally different in cases where many plants mutate in the same direction from cases where they mutate in different directions.

Both aggregate and promiscuous mutations have been described in the same species, the garden tomato, the former by Dr. C. A.

[a] Another experiment at the San Antonio Experiment Farm in 1908 gave similar results. Plantings of March 14, March 27, and April 25 yielded at the rate of 1,040, 1,099, and 1,142 pounds per acre, respectively. See Headley, F. B., and Hastings, S. H., The Work of the San Antonio Experiment Farm in 1908, Circular 34, Bureau of Plant Industry, p. 16.

White,[a] of Washington, D. C., the latter by Prof. E. P. Sandsten, of the Wisconsin Agricultural Experiment Station. In Doctor White's experiments whole plantings changed in the same direction, as in the case of our Parker cotton at Del Rio. In the Wisconsin experiments great individual diversity appeared, as in newly imported Central American cottons:

> The results of this excessive application of fertilizers soon became apparent. Hardly two plants in the bed of ninety-six were alike in all particulars. The stems in many plants were more or less decumbent, in others the internodes were elongated. A few plants were more or less dwarfed. The leaves showed marked variation in size, shape, and subdivisions; the whole bed giving an appearance of a variety test. The variation became more marked at the time of flowering. In many instances the blossoms were abnormal, both as to size and form. The stamens were greatly modified in several of the plants, and in one instance to such an extent as to become almost aborted. On the other hand, the pistils were greatly thickened and overgrown. One plant in particular, which showed marked modifications in the floral parts, was labeled and carefully watched. As the fruit grew it was noticed that the pistil and fleshy part of the ovary developed abnormally and there appeared to be no evidence of seed formation. During the process of growth and ripening of the fruit this fact was further emphasized, and when the first fruit was cut it was found to be seedless. The growth habit of the plant, while not excessive, showed a marked deviation from the ordinary type. The leaves were more divided and somewhat curly; they were also much smaller, and the general habit of the stem and branches was more or less decumbent.[b]

An aggregate mutation of many plants in one direction has greater resemblance to a change of adjustment or accommodation than has a promiscuous mutation, where each plant appears to change in a different direction, but the promiscuous mutation appears rather less remarkable than the aggregate if we consider that the external conditions have only disturbed the previous adjustments of the characters, without inclining them toward any particular new adjustment. As a matter of fact, the two forms of mutation are often closely associated in the phenomena of acclimatization. An aggregate mutation of all the plants to a different habit of growth is usually accompanied and followed by many and very promiscuous changes in other characters. A serious change in a character that is affected by the external conditions may be followed by changes in many other characters that have no apparent connection with external conditions.

The facts of mutation forbid any reliance in practical agriculture upon the idea that a stock which has been rendered uniform by selection will remain uniform if selection is relaxed. This idea certainly does not rest upon the observation of varieties as they are, but

[a] The Mutations of Lycopersicum. Popular Science Monthly, vol. 67, p. 151.

[b] Sandsten, E. P. Excessive Feeding as a Factor in Producing Variations in Tomatoes. Twenty-second Annual Report of the University of Wisconsin Agricultural Experiment Station, pp. 301–304. 1905.

is an inference from the theory that evolution takes place by sudden changes of characters, like those that distinguish a mutation from the parent variety or from another mutation. An open-fertilized plant like cotton is more readily variable and hence more susceptible to new-place effects than a strictly self-fertilized plant like wheat or barley. Nevertheless, it appears that self-fertilized plants are far from being immune to variation. Even in vegetative varieties the different stocks derived from the same original individual may become very diverse as a result of bud variation, or may show different degrees of vigor and fertility.

Acclimatization appears to be especially difficult with carefully selected, line-bred, self-fertilized varieties, such as those of wheat and barley. Specialists in these crops consider that the carefully selected stocks are much less likely to become acclimatized or adjusted to a new place than the types that have not been so carefully selected. A whole planting may show the same variation at the same time, an aggregate mutation instead of a promiscuous mutation, giving only one chance of adjustment to the new conditions instead of the vast number of chances afforded by promiscuous mutation. It is possible that something might be gained in such cases by making the experiment of acclimatization or local adjustment with cross-fertilized seed as affording a better opportunity for the display of a useful diversity.

RELATION OF SELECTION TO LOCAL ADJUSTMENT.

One of the reasons why the phenomena of local adjustment and acclimatization have been so largely overlooked and left out of account as factors of practical importance in agriculture is to be found in the general popularity of the idea that selection brings about the progressive improvement of plants and animals, as held by many writers on evolution. But for general scientific purposes as well as for practical reasons it is important to understand how the beneficial effects of selection are exerted. Ever since Darwin's first writings on the subject of natural selection were published the chief objection to his doctrines has been that they did not explain how selection could bring into existence the new or improved characters shown in the evolutionary progress of species. It has to be admitted that selection, whether natural or artificial, must deal with variations as accomplished facts. Selection gives one variation or characteristic a great advantage over other alternative characteristics, and thus allows it to become more quickly the character of a whole variety or species. Thus, natural selection might assist in diversifying two parts of a species that were living under different conditions, just as artificial selection may develop two or more different strains from one variety by saving in some groups the variations

that are rejected in the others. But in all such cases selection still deals with differences as they appear, and does not help us to understand the nature of the differences themselves, or the factors that are responsible for their appearance.

Selection for local adjustment deals, like natural selection, with forms and characters that already exist in the plants; the question of improvement by further changes is not involved. The benefit that is secured when local adjustment is accomplished through selection is simply that of bringing the variety back to its previous standard of uniformity. Instead, therefore, of saying that local adjustment and acclimatization are to be explained by reference to selection, we ought rather to recognize that the facts of local adjustment and acclimatization throw light on the workings of selection. We must recognize the influence of external conditions to call forth diversity before we can understand the effect of selection to improve the variety again by restoring it to uniformity of expression. The Triumph cotton had already had the advantage of persistent selection, and shows the result in great uniformity. But when new or unfavorable conditions disturb this uniformity, a new "improvement" becomes possible through selection for a new adjustment to uniformity of expression of characters. It is this secondary selection that becomes particularly necessary to restore the uniformity of varieties in new places that we call local adjustment. The name, of course, is quite incidental to the recognition of the fact that changes of such great practical importance occur in our varieties and that they may be so easily corrected.

The fact that the selective improvement of domesticated varieties is a process of reducing or eliminating the individual diversity found among the members of wild species agrees completely with facts revealed in other lines of study. The individual diversity among the members of a wild species is generally very much greater than among the members of a domesticated variety. A progressive approximation to uniformity is attained through selection. The indication that the diversity is never entirely eliminated by selection, but is merely suppressed and is able to reassert itself after many generations, is also in full agreement with all the numerous facts of atavism and reversion. It is possible to understand that most of the changes which we ascribe to selection represent changes in the expression of characters already existing in the plants, and do not require the origination of any new characters not already developed in the more diverse ancestral groups from which our domesticated stocks have been derived.

It is sometimes supposed that uniformity represents the natural condition of reproduction and that all deviations must be due to

hybridization. Nevertheless, the scientific world now generally recognizes the fact that sports or mutations do occur, that is, definite changes in the expression of character in members of otherwise uniform groups, without any admixture of blood. What has not been recognized hitherto is the fact that such changes are not necessarily confined to rare individual variations, but may take place simultaneously in large numbers, following changes of external conditions.

LIMITATIONS OF LOCAL ADJUSTMENT.

The process of local adjustment may be said to have been completed when a variety has become as uniform in a new locality as it was in the district where it originated or improved by selective breeding. It is not to be expected, however, that diversity will cease entirely. It does not appear that any amount of selection can prevent the transmission of the ancestral diversities or prevent the return of some of them to expression in occasional individuals. The most careful and persistent breeders have never succeeded in putting an end to the appearance of mutative variations. And even if we consider that the characters of the plants should remain uniform as long as the conditions remained the same, there would still be the difficulty that conditions are always differing, even when we try to make them as nearly alike as possible.

The effects of an unfavorable season may greatly overbalance the advantage that can be gained through selection for local adjustment in a favorable season, and may even increase the amount of diversity beyond that of the first year. It is accordingly to be expected that the second year of a new variety will sometimes be found inferior to the first year, in spite of an attempt at local adjustment.

Change of the crop from one soil to another may have its effect upon local adjustment, even in a favorable season, or may intensify the effects of an unfavorable season. The advantage that could be ascribed to local adjustment in our experiment at Del Rio, Tex., in 1907, was very slight in comparison with that shown at Kerrville, Tex., in the same season. In some of the varieties no advantage at all could be detected. Some of the selections brought from San Antonio or Victoria were better than those made at Del Rio in the preceding year. A change of the location of our Del Rio experiment from a gravelly slope, recently leveled for irrigation, to the deep silty soil of the river bottom gave a reasonable explanation of the discrepancy of results with respect to local adjustment. The Del Rio crop of 1907 was very much better than that of 1906, but the Del Rio selections from the crop of 1906 showed little or no superiority in 1907 to those brought from other places.

The conditions of the experiments of the two years at Del Rio were as essentially different as though they had been in distant localities.

The failure of the local adjustment effects to appear should be considered as confirming the reality of the phenomenon. On the other hand, it ought not to be thought that the excellent behavior of some of the Victoria and San Antonio selections under the very favorable conditions at Del Rio in 1907 would have been shown if they had been grown under the Del Rio conditions of 1906.

A bad season or an unfavorable location should not lead the farmer to suppose that his efforts for local adjustment must necessarily fail. Even though none of the plants in the field attain the full stature and fertility of the variety, the opportunity of selection is not necessarily destroyed. Plants that excel their neighbors under unfavorable conditions are likely to yield progeny that will show a corresponding excellence under better conditions.

Professional seed growers appreciate the fact that somewhat unfavorable conditions may render the work of selection more efficient than conditions that are ideal from the standpoint of crop production. Unfavorable conditions invite the appearance of unfavorable tendencies and thus facilitate the removal of the lines of descent in which these tendencies are strongest.

Very unfavorable conditions during the period of seed production may also prove to have an influence in local adjustment, since the adverse effects might not appear till the next generation. It is easy to understand that plants may develop normally while conditions are favorable, and yet fail to set equally normal seeds if the conditions became unfavorable. Many crop plants will complete their development in an apparently normal manner under conditions where they produce only inferior seed. The fact that the period of seed production is very long in cotton enables this plant to furnish even more definite evidence of the influences of external conditions, for the seeds and lint are often found to differ notably on the same plant.[a]

Instances may also be found where efforts at local adjustment will fail to bring a variety to a satisfactory degree of uniformity. It is not to be expected that a variety that fails to respond to local adjustment and return to a uniform behavior will equal a well-adjusted variety. If a variety fails to respond to local adjustment after a fair opportunity, it will be reasonable to consider the conditions are really not favorable; that the stock has been hybridized, or that it has never been brought to a condition of uniformity.

In view of the wide differences of soils and seasons that may be encountered on the same farm, ability to withstand changes of conditions without being injuriously affected is a factor of great importance in a field crop like cotton. There is no reason to suppose that the

[a] A Study of Diversity in Egyptian Cotton. Bulletin 156, Bureau of Plant Industry, U. S. Department of Agriculture. 1909.

injurious changes of characters are entirely confined to strains of cotton that have been carried recently to new places. An unusual season may render conditions quite as exceptional as a new place and may have the same effect of arousing diversity.

In considering the use of local adjustment as a means of removing or reducing these undesirable diversities there is no need to lose sight of the fact that varieties of cotton and other plants undoubtedly differ greatly in their relation to the local adjustment factor. Varieties that can not have their conditions changed without becoming injuriously diverse must be reckoned in the same general class as those that are narrowly adapted in other respects and refuse to thrive or to bear fruit outside of some particular district. Other things being equal, varieties less subject to disturbances of expression relations are always to be preferred. With cotton it would be very desirable if only one variety of cotton were grown over a large district, since the uniformity of the product is a factor of commercial importance.

DIFFERENCES BETWEEN LOCAL ADJUSTMENT AND BREEDING.

Though the work of local adjustment may be considered as a part of the art of breeding, in the largest sense of the word, the process of local adjustment is quite distinct and in some respects is even opposed to the processes that are usually given prominence in the improvement of varieties by breeding. The breeder seeks for new characters or new combinations, or to obtain still higher degrees of expression of desirable features, for something exceptional and different from the recognized varieties. By local adjustment, on the other hand, we do not seek to change the variety, but to prevent change by rejecting all the lines of descent in which changes appear.

When the commercial seed grower pulls out the "rogues" or "off" plants that do not "come true" to the characters of the variety he is not usually thought of as engaged in breeding, but only as preserving his stock from deterioration. The work of local adjustment is exactly analogous to the "roguing" of a variety. We are simply recognizing the fact that the transfer of seed to new conditions is likely to produce such large numbers of rogues that it is necessary to extend the roguing process from the hands of the seedsman to those of the farmer. The seedsman who does not practice roguing is reckoned as dishonest, because he does not sell "pure" seed, but allows seeds of rogue plants to be mixed in with the variety that he offers for sale. The farmer who neglects local adjustment need not be considered dishonest because he may not injure anybody but himself, but he is at least depriving himself of the advantage that he expects to secure from the seedsman.

Seedsmen not only pull out rogue plants that show definite differences in the characteristics of the leaves, flowers, or fruits, but they also take into account differences of behavior of the plants with respect to such qualities as vigor, fertility, and earliness. They know that the extent to which a variety may adhere to these desirable qualities depends largely upon the conditions under which it is grown. They recognize that even a slight departure from the normal qualities of the variety is likely to arouse more persistent differences in later generations, especially if the influence is repeated. A careful study of the behavior of varieties of garden peas with respect to the quality of earliness has been made by Mr. W. W. Tracy, sr., who states the following conclusions:

> Seedsmen commonly believe that, in the case of peas the character of the soil has a marked influence over the character of the plant, and that this influence extends to and is carried by the seed, but that such soil influence is decidedly cumulative in its effects, so that in practice they attach little importance to it for one season, but carefully avoid the use of stock seed which has been submitted to such influence for consecutive years.[a]

It is sometimes said that farmers ought to be as much interested in the breeding of their domestic plants as in the breeding of their domestic animals, because the practical importance is as great in the one case as in the other. This is undoubtedly true of the work of breeding as a whole. Local adjustment, however, is a subject which appears to have much more importance with plants than with animals, for plants are more susceptible than animals to changes of external conditions. Temperature is undoubtedly one of the chief factors that induce changes of characters in plants, whereas all of the higher animals and birds maintain their own temperatures with great constancy and have thus eliminated one of the chief agencies that disturb the hereditary processes of plants. Plants have to adjust themselves to wide extremes of external conditions of climate and soil, while many animals have large liberty of choice of environment.

The possibility of obtaining desirable variations by placing plants under conditions that call forth a wide range of diversity is worthy of careful consideration from the standpoint of the breeder, as an alternative of hybridization. The fact that a great majority of the variations are undesirable does not preclude the possibility that individuals of special excellence may sometimes be found, from which superior new varieties may be obtained, as from other mutations. The Triumph cotton itself is said by Mr. Mebane to have originated from a single peculiar plant of the Texas Stormproof variety, a plant that

[a] Tracy, W. W., sr. The Influence of Climate and Soil on the Transmitting Power of Seeds. Science, n. s., vol. 19, p. 739. 1904.

had all the present characteristics of the Triumph definitely developed. While there is nothing to show that the subsequent selection has changed or "improved" the variety, it has served the important purpose of maintaining its uniformity and productiveness.

Diversities that can be secured without hybridization may be found more valuable than the others, especially in seed-propagated plants, where the persistent diversities of hybrids seriously interfere with their utilization. This difficulty of "fixing the characters" is avoided in the case of the mutations, which are often constant from the first.

In local adjustment we have no interest in these possibilities of obtaining new varieties. Divergent plants, even though they may be as good or better than the regular stock of the variety, should not be retained unless they are to be separated for breeding purposes. To keep them in the field and allow their progeny to become crossed with each other and with the parental type is only to lose the new strains without making the old one any better. The same result is to be expected as when distinct varieties are crossed. The first generation may not be inferior, but later generations are likely to call forth a degenerative diversity similar to that which we seek to avoid by local adjustment.

In acclimatizing imported varieties it has appeared that the selection of types that depart from the usual form of the stock in its previous habitat is likely to delay acclimatization, for these are not as likely to "breed true" as plants that return more nearly to the accustomed form of the variety. There may prove to be a relation between the stability of new variations and the constancy or uniformity which has been attained in the stock in which variation appears. The constancy of the new forms is likely to be greater in local adjustment, for they appear to be more closely of the nature of mutations. Our experiments have not been carried far enough to determine the point, but it has appeared thus far that some of the variations that are aroused in new localities are likely to be as constant as the parent stock, or even more so.

The failure in the past to distinguish local adjustment from breeding is undoubtedly responsible for some of the apparently contradictory facts that have been reported. Local adjustment enables us to understand why large increases of yield can be secured at once by simple selection in the first year or two, and also why no similar rate of "improvement" is obtained in later years, after the variety has been brought to a condition of approximate uniformity.

The methods of breeding which are supposed to bring about true improvements of varieties by individual selection usually need to be practiced on a larger scale and with greater precautions against accidental errors than most farmers are willing to apply. Either the

work is found too difficult and expensive or the numbers of plants that can be tested become so small as to seriously reduce the prospects of success. If we narrow our stock to progenies of a few individuals, these progenies have to be most carefully tested, for if a wrong selection be made permanent damage is done. The best stock may be lost by mere accident, and the accident may go unnoticed unless elaborate precautions are taken to equalize the conditions of the tests.

The more unstable or degenerate a variety is the more frequently will it show a marked response to selection. It is often assumed that the true value of a selected stock can be shown by comparing it with an unselected stock of the same variety, but the difference between the two ought rather to be looked upon as an index of the extent to which the unselected stock has degenerated. The true value of the selected stock can only be judged by comparison with equally selected and locally adjusted stocks of other varieties, to see which will show the best and most regular performance under the given conditions. Other things being equal, a stock ought to be considered better that does not "respond" to selection, for this indicates that all the individuals are nearly equal in their inherent qualities, whereas a stock that regularly shows a marked improvement from selection gives at the same time evidence of a more prompt and persistent recurrence of diversity, as a more frequent factor of deterioration and loss, unless more stable strains can be separated by selection.

The wide differences in yield which breeders have found among the progeny of individual members of carefully selected stocks are usually cited as proofs of the value of continued selection, but excessive variability of yield may also indicate that the stock is deficient in local adjustment or that it has reached a condition of serious degeneration. An interesting example of diversity in yields among a series of selections of cotton grown under the same conditions has been published by Mr. A. M. Ferguson in the Texas Stockman and Farmer for March 31, 1909. Out of 28 selections 12 gave total yields at rates of from 1,218 to 1,529 pounds per acre, while 13 selections fell below 1,000 pounds per acre, 8 below 900, 4 below 800, and 1 below 700, the figure in this case being 674 pounds. The yields from the first of the two pickings were even more unequal than the totals, ranging from 127 pounds per acre to 1,348 pounds.

If a large proportion of the progeny regularly prove to be deficient the only remedy may be to secure a better stock, one that is more uniformly fertile. A stock that gives us too small a proportion of high-grade plants may be less desirable than one that gives a larger proportion of plants of less conspicuous excellence. Many of our carefully selected stocks, both of animals and of plants, fail to maintain the standards of fertility that would be expected among normal

individuals of an ordinary "mixed population." It is often assumed among breeders that strict uniformity in other varietal characteristics carries with it an equal uniformity of vigor and fertility, but this relation has not been established as a fact outside of varieties that are propagated by line breeding, and even these may deteriorate.[a]

Vigor and fertility represent physiological standards of organic efficiency. They are not to be looked upon as characters in the same sense as the minor details of color, shape, or function, but are rather to be considered as cooperative results of the activities of other characters and functions. It has yet to be shown that greater vigor or fertility can be attained in groups that are restricted to the expression of a single set of characters than in groups of greater individual diversity.

A further difference between local adjustment and breeding may be found in the fact that the diversities which make local adjustment a necessity are in some important respects different from those with which the breeder must deal in establishing an improved strain from a stock which has not been previously subjected to careful breeding. Though we may think of the diversity that arises in a new place as a return toward the diversity that existed before the variety had been rendered uniform by selection, the new diversity does not appear to be altogether the same as that of a group that has never been closely selected.

In an unselected wild stock the plants are individually different, but the differences are harder to detect because of the presence of many intermediate gradations. Ordinary "mixed populations" of animals or plants obey Galton's law of regression and tend to resemble their immediate parents instead of their remote ancestors. In a wild type the law of regression would aid natural selection in bringing the more favored characters into expression in larger and larger proportions of the freely interbreeding population. Mutations, on the other hand, do not appear to obey the law of regression, but may go back definitely to a character of a remote ancestor and show no influence from the immediate parents or grandparents.

In addition to bringing back the normal diversity of the wild type into expression mutative variations have two other very important elements of diversity. The first element is the diversity of more remote ancestors that would not tend to appear or to remain in expression under conditions of regression and free interbreeding. The second element is the suppression of many normal characteristics and coordinations, as in the cluster habit and the bullate leaves or the loss of fuzz or of lint. Darwin and many other writers have noted the

[a] The Superiority of Line Breeding over Narrow Breeding. Bulletin 146, Bureau of Plant Industry, U. S. Department of Agriculture. 1909.

general tendency of plants recently introduced into cultivation to "break" into diverse varieties.[a]

In strictly self-fertilized varieties like those of wheat and other cereals, selection can be said to have only one effect; it makes a stock more uniform in proportion as the diversities are rejected. Conditions of reproduction in the lines that are preserved are in no way affected by the taking away of the other lines. In plants that are subjected to frequent cross-fertilization, as in cotton, the selective restriction of descent to narrow limits or to a single line has an indirect effect upon the heredity of the plants that remain. It renders them much more uniform than before; that is, much more regular or "fixed" in the expression of their characters. While never attaining exact likeness, the great majority of them may differ only in the extremely slight details, usually termed "fluctuating variations" by writers on heredity. Plants that have attained this condition of uniformity, so that they show only fluctuating differences and produce progeny of equal uniformity, are said to be "pure" or homozygous, in the technical terminology of Mendelism. They tend more regularly to bring into expression only one set of characters instead of the indiscriminate diversity of wild species or of "unimproved" domesticated stocks.

Writers on Mendelism look upon self-fertilization as a means of separating the lines of descent that are uniform or homozygous from those that are diverse or heterozygous, as in the case of Mendelian

[a] "While specific stability under constant conditions appears to be the rule in nature, it is widely different in cultivation. When a plant is brought under cultural conditions it maintains its type for some time unaltered, then gives way and becomes practically plastic. From my experience at Kew, where I saw the process continually going on, I hazarded the generalization that any species, annually reproduced from seed, could be broken down in about five years.

"In nature we deal with a host of individuals; in cultivation with a very limited number. In my view specific stability is maintained partly by the weeding out of unfavorable variations, partly by wide interbreeding. Now, it is obvious that under cultivation the latter agency is inoperative, and cultural conditions bring other influences to bear, especially as regards nutrition.

"The races of Œnothera which De Vries has raised are nothing more than what a horticulturist would expect; and it may be conceded that if such races could hold their own in nature, distinct species might originate in this way. But there is no evidence that they do; and the probability of their being able to do so is against them.

"Cultural mutations seem, as a matter of fact, to have little, if any, capacity for holding their own in the struggle for existence. I can not call to mind a single instance of one which has been successful, and even in cultivation there is some reason to think that they are short lived; but this is a point on which we are in urgent need of carefully ascertained facts." See Thiselton-Dyer, W. T., Specific Stability and Mutation, Nature, November 28, 1907, pp. 78 and 79.

hybrids. It ought also to be recognized that self-fertilization and other forms of restricted descent serve to establish the homozygous condition so that uniform progeny are produced instead of diverse progeny. The persistent application of a standard of selection tends to establish that standard for larger and larger proportions of the progeny unless degeneration ensues. Even the variations of homozygous stocks usually remain homozygous, though the act of variation is in itself a violation of the rule of homozygous uniformity.

A line-bred variety tends to become "pure" or homozygous in all its characters, whereas broad-bred, cross-fertilized varieties may become homozygous in only a part of their characters, those that are specially selected. It appears to be possible to secure a considerable degree of uniformity in a desirable character without establishing uniformity in all other respects; that is, without placing the variety on a basis of complete line-breeding, which is a practical impossibility in open-fertilized plants grown as field crops, like corn and cotton. Varieties of corn attain a highly characteristic uniformity of ears without enforcing a requirement of uniformity in the plants. Egyptian cotton also has a high commercial reputation for uniformity, but has not been made uniform in vegetative characters to any such extent as some of our Upland and Sea Island varieties.

Selection for local adjustment of established varieties is much more practicable for the farmer than selection for breeding in unimproved strains. It is much easier to detect an aberrant individual in a group of plants otherwise closely similar to each other than to appreciate individual differences in a group where the diversity is general and indiscriminate. Variations that take place in varieties that have been bred previously into a uniform or homozygous condition are much more definite and hence more easily perceptible than the less definite differences found in unimproved varieties. Too much diversity will greatly increase the difficulty of selection for local adjustment, unless the farmer is thoroughly familiar beforehand with the normal type of his variety. Unless we are able to distinguish the type of the variety our efforts will only result in the saving of a collection of varieties, and the further mixing of these together can only mongrelize the stock still more.

LOCAL ADJUSTMENT AS A FARM OPERATION.

The facts of local adjustment will have a practical value to the farmer in proportion as they are able to convince him of the necessity of selecting his own seed. If by the light labor of selecting his seed from normal fertile plants he can increase the quantity and quality of his product from 10 to 20 per cent, he must recognize the fact that such selection is quite as practical a farm operation as planting, cultivating, or harvesting the crop.

The labor of such selection is very slight. It is not necessary to establish any absolute standards or score cards, and in almost every family there are men, women, and children well qualified by natural acuteness of observation to recognize the plants that are more fertile than their neighbors and to avoid those that deviate from the characters of the variety or have short, weak, or sparse lint. Normal characters and habits of growth, fertility, and good and abundant lint are the only features that need to be taken into account in maintaining the local adjustment of a variety. Selection for this purpose is a matter quite apart from the breeding of new varieties or of special strains by careful comparison of single individuals and the progeny derived from each.

Differences in vigor or fertility that can not be distinguished in the individual plants themselves will become apparent when the progenies of these individuals are compared. Selective breeding by means of progeny rows is a further step beyond local adjustment that will give the farmer a further improvement of his crop if he will take the additional pains that this system requires in raising the progenies separately, and keeping the stock pure. It is a mistake, however, to suppose that even the progeny row is a full substitute for local adjustment as a means of guarding a superior stock against deterioration. No matter how excellent a variety may be or how skillful the selection of the professional breeder who may have perfected it, the farmer will still need to maintain its efficiency by his own selection if he is to get the best possible results of productive efficiency.

SUPERIORITY OF HOME-GROWN SEED.

In thus urging upon the farmer the necessity of maintaining the local adjustment of whatever variety of cotton he may prefer to grow there is no intention of pronouncing any general conclusion on the much debated question of the superiority of home-grown seed over imported seed. One or the other of these alternatives is often argued as a general principle or policy of agriculture, whereas the question is really very complicated. Different principles have to be considered in relation to different crops. The growing of the seed of many highly specialized varieties of ornamental plants and garden vegetables, such as cauliflower and radishes, is confined to a single locality. By very careful treatment on the part of the grower the problem of local adjustment can often be avoided. A single crop can be secured from the imported seed, even under conditions where no good seed can be raised for a second generation, but with a field crop like cotton that can not be protected against variations of climate and soil the case is very different.

And even with cotton itself it is not to be expected that local adjustment will give equal advantages in all cases. Some localities may profit by the regular importation of seed from other districts. Experiments with newly imported cottons have shown in a few cases larger crops in the first year than have been obtained in later plantings of the same stocks. In such cases the transfer to new conditions, instead of throwing the plants out of adjustment and producing an injurious range of diversity, seems rather to give an unusual stimulation of growth, without inducing the sterility which usually accompanies such stimulation. Two instances were found at Del Rio., Tex., in 1908, where seed brought from Falfurrias, Tex., produced rows of plants that were distinctly larger than rows of the same varieties (Parker and Cook's Improved) grown from seed raised at Del Rio. But in both these instances the greater size was accompanied by a decrease of fertility, or at least of earliness. Thus no practical benefit was shown for such an exchange of seed.

With a forage plant or other crop grown for vegetative tissues alone a response of the same kind might afford a distinct advantage. If it can be found that the bringing of seed from one region to another uniformly results in such a desirable stimulation, and especially if it is accompanied by increased yields, such transfers of seeds between particular regions will need to be recognized as a regular feature of the agriculture of particular crops. This is a very different idea, however, from that of general advice for or against "change of seed."

Just as the diversity which arises in a new place may be compared to the diversity which comes by crossing, so it may be that a useful increase of vigor can be secured merely by placing plants under new conditions, like the vigor that comes from crossing. In both cases it is possible to think of the vigor as attending a change of characters, and this fact may be connected in turn with the further fact that varieties held rigidly and long to one uniform set of characters appear to suffer an eventual deterioration.

Though future experiments must determine the value of local adjustment in its application to particular varieties and conditions, our present facts are certainly sufficient to show that the usual methods leave out of account a physiological factor of great practical importance. Every farmer who plants the same variety for even a second year from seed of his own raising will find it to his distinct advantage to take the fact of local adjustment into account. He need not think of the advantage of selection of seed as connected only with a policy of slowly improving his stock by a persistent selection through a long course of years. He may secure a very distinct and practical advantage by selecting his seed for a single season, even if

he intends to stop farming the year after, or to discard the variety he is now planting. While there is every reason to expect that a slow improvement may be wrought by persistent selective breeding, the neglect of local adjustment means that we forfeit the chance of making an immediate gain or of protecting ourselves against an immediate loss.

The selection of seed has seemed, even to the progressive cotton planter, as something out of his line of work, something to be done by the special grower or the seed dealer. Intelligent planters appreciate the importance of good seed, but they are usually content to show this appreciation by bringing in some well-recommended variety from a distance, growing it for a series of years until it appears to "run out," and then replacing it by another new stock. The fact that the new sort is often found to be better than the old is still accepted as proof of the value of this custom, notwithstanding all the evidence of experiments and demonstrations that better crops of cotton can be grown from seed raised in the same place than from seed newly brought in from a distance. The advice of the seed dealer to change the seed has appeared to the farmer to have quite as good reasons behind it as the advice of the experiment stations to make his own selection of seed.

Unless a fact is properly understood we can not separate it from its apparent contradictions. New seed may be better than home-grown seed if no selection has been practiced, but, on the other hand, the best new sort may fail to show its full possibilities when planted for the first time in a new place. Even the very best variety may need to be selected in the place where it is grown to get the best crop. The superiority of new seed and the superiority of home-grown seed are both facts, and they are not contradictory as they have long appeared to be. They help to explain each other when viewed in the proper light. The farmer can raise better seed of his present variety for himself than he can possibly buy from a dealer, but this does not mean that he is not to look for better varieties. It means rather that promising varieties must have fair chances to show what they can do by testing them for two or more years instead of judging their possibilities by the results of the first planting.

CONCLUSIONS.

The growing of a variety of cotton in a new locality is likely to bring about a distinct reduction in the yield as well as in the quality of the fiber. This deterioration has been found to be connected with an increase of diversity among the individual plants. Even when a carefully selected, uniform stock is used for the experiment a much greater amount of diversity may appear in a new place than when

the same stock is grown under accustomed conditions of the previous locality where the variety was improved by selection.

The diversity that reappears in the first season when a variety of cotton is grown in a new place can be greatly reduced in later seasons by selecting seed from the plants whose characteristics have been least disturbed by the transfer to the new place—those that are the most fertile and have the best lint. This process of selection to restore the uniformity of a variety in a new place is called local adjustment.

Selection for local adjustment is distinct in objects and methods from breeding for improvement or for originating new varieties. The object of local adjustment is to preserve varieties already existing and guard them against recurrence of diversity. Practical advantages can be secured by simple selection for local adjustment without the separate testing of individual lines of descent, as required in breeding for improvement of a variety or when new breeds are to be developed.

The phenomena of local adjustment are of general scientific interest as illustrating one of the influences of external conditions upon the expression of characters in organisms. The recurrence of diversity in a previously uniform variety serves with other facts to show that ancestral diversities continue to be inherited, even when their expression is avoided by efficient selection. That changes of conditions can induce a return to diversity shows that the environment is able to influence the expression of characters and that its influence is not limited to characters that vary directly and regularly with changes of environment.

Apart from the effects of conditions which limit or inhibit the growth of the plants, two kinds of changes are found to follow transfer to new places: (1) Changes of accommodation to different conditions and (2) diversification or loss of uniformity. Changes of accommodation do not directly increase diversity, for they are shared by all the individuals, but changes of accommodation are often accompanied by changes of other characters which render the individual plants much more unlike than before.

It is not necessary to believe that the diverse characteristics that appear in the new place come into the plants from the external environment or that they represent direct effects of the environment upon the plants. It is more reasonable to suppose that new conditions induce diversity in an indirect manner by disturbing the processes of heredity, and thus allowing ancestral characters that had been transmitted in latent form to return to expression, or characters previously expressed to become latent. Recurrence of diversity may be quite independent of hybridization, although some of the results are very similar.

The phenomenon of local adjustment only strengthens the many other evidences that the uniformity of a variety of cultivated plants can be maintained only by persistent and vigilant selection. The decrease in the agricultural value of a variety that results from a return to diversity is as real and important as the agricultural improvement that is made when diversity is reduced by selection.

The facts of local adjustment go far to explain the apparently capricious behavior of cotton varieties in comparative tests, the same varieties often standing in entirely different relations to each other in different seasons. It becomes evident that the adaptation of a variety to a new place can not be fairly tested in a single season. Not until a new stock has passed through the process of local adjustment and returned to a normal degree of uniformity can the extent of its adaptation to the new place be definitely ascertained.

The facts of local adjustment indicate that our superior varieties may be found adapted to much wider regions than they now occupy. Varieties of real value should have their range extended through local adjustment, instead of being discarded because they fail to show their superiority in the first season. The wider extension of a few superior types of cotton would make it possible to abandon many local varieties and would constitute an important step in the progress of the cotton industry. Greater uniformity in the crop over large areas would increase its commercial value and simplify commercial problems of grading and marketing.

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